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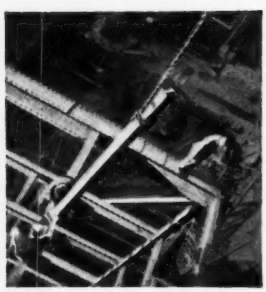

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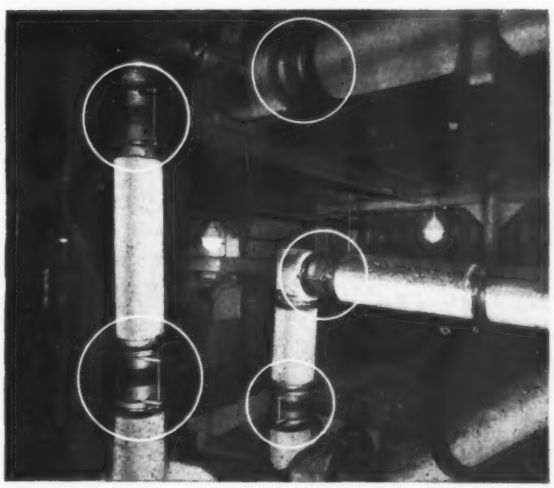

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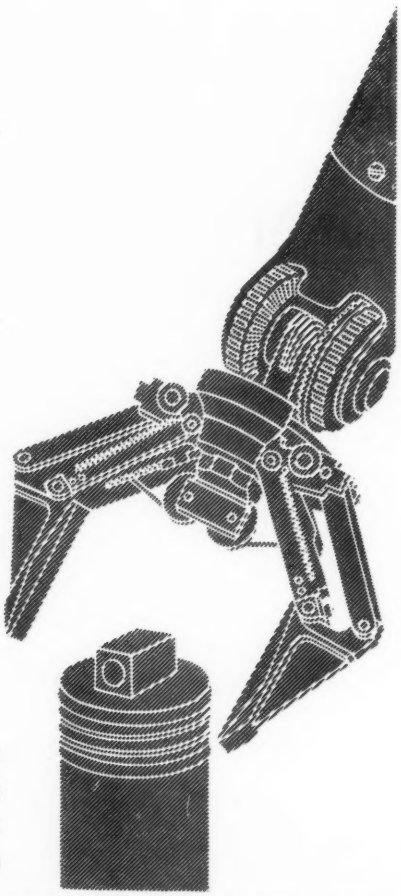

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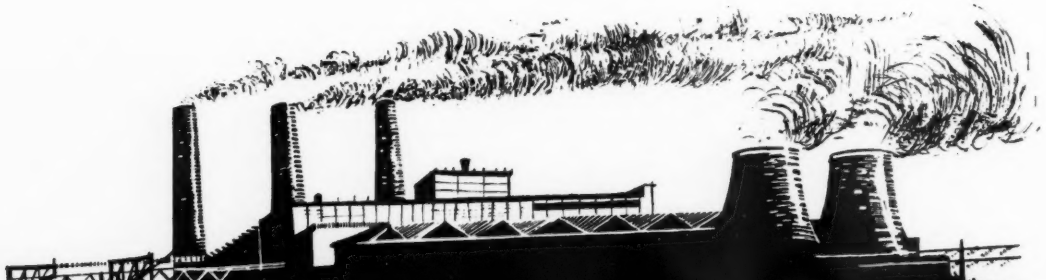

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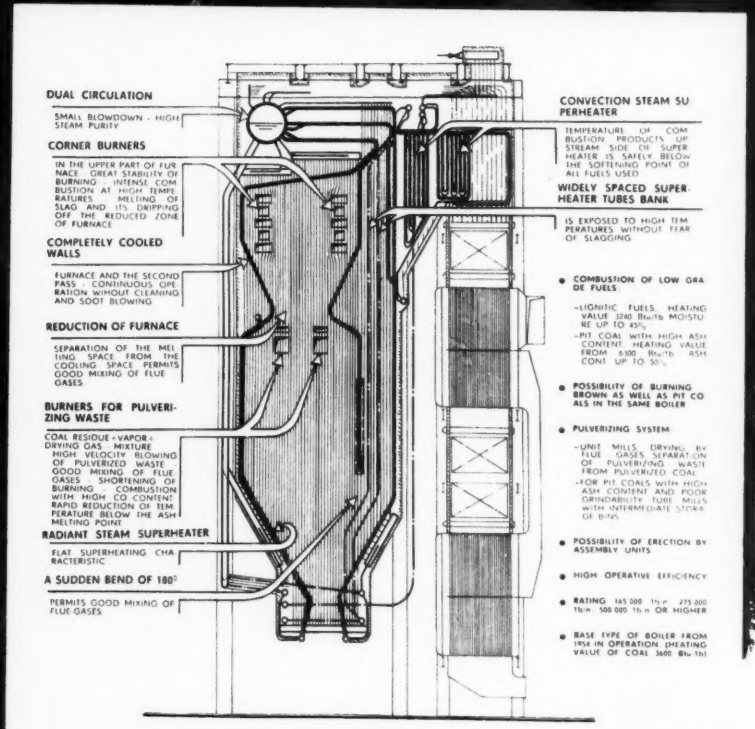
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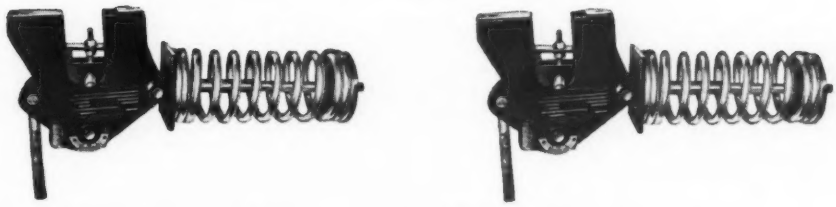

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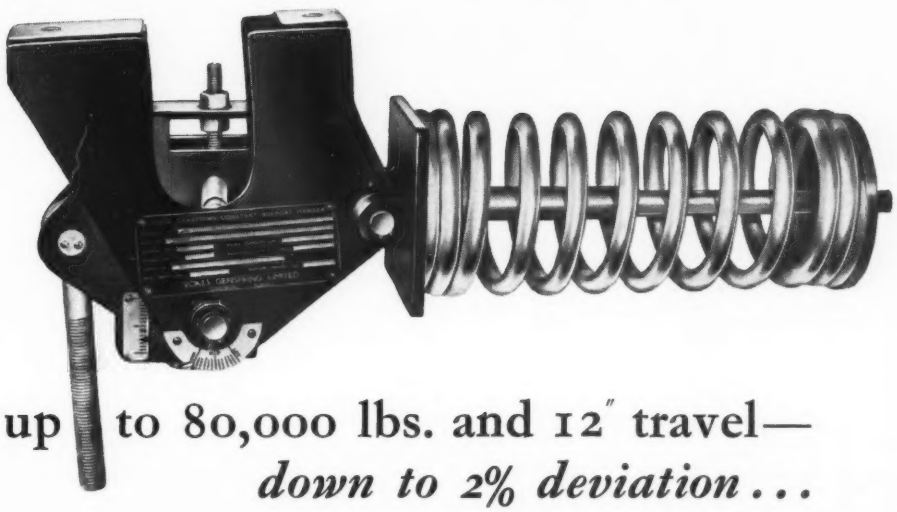

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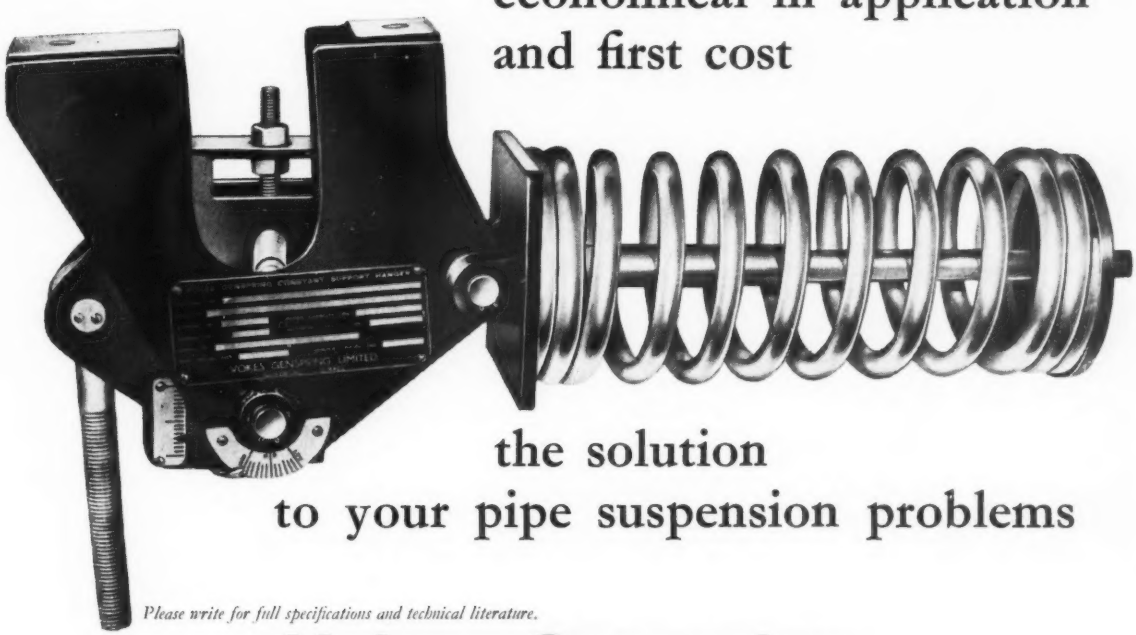

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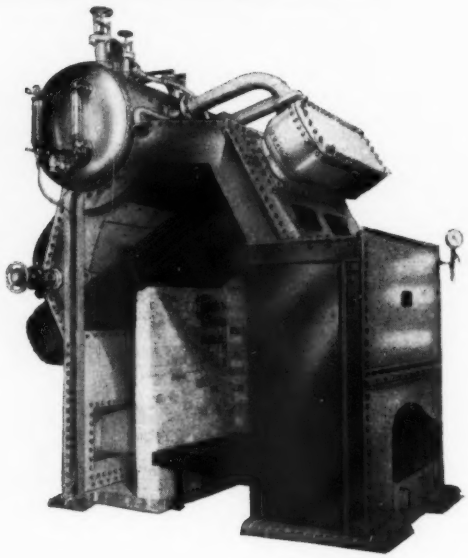

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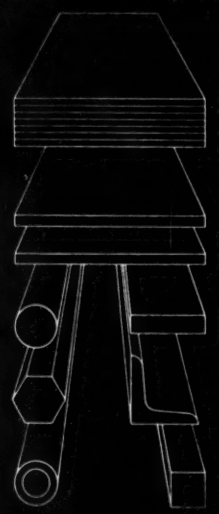

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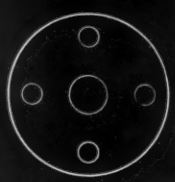

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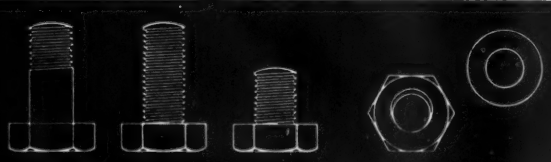

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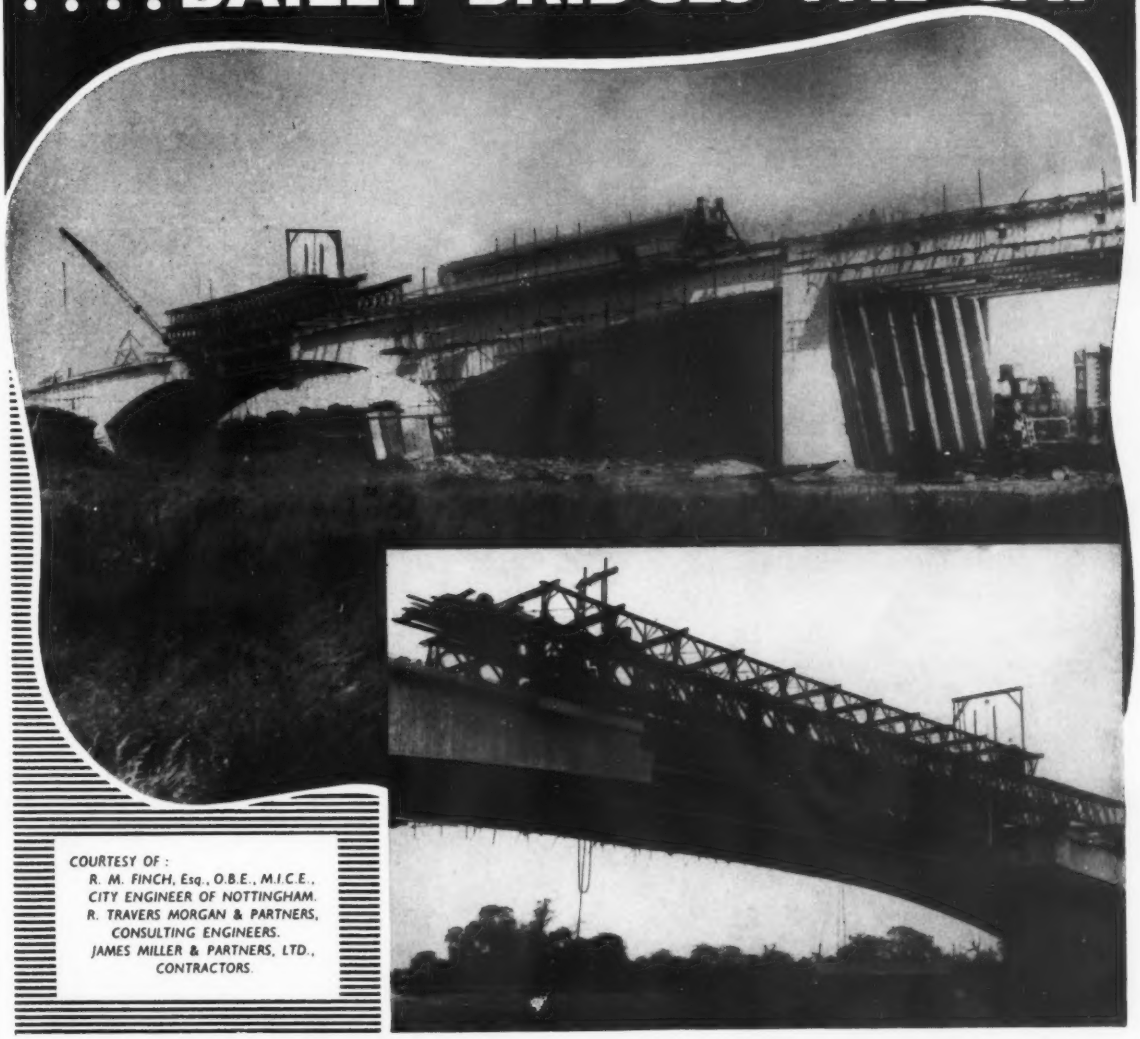

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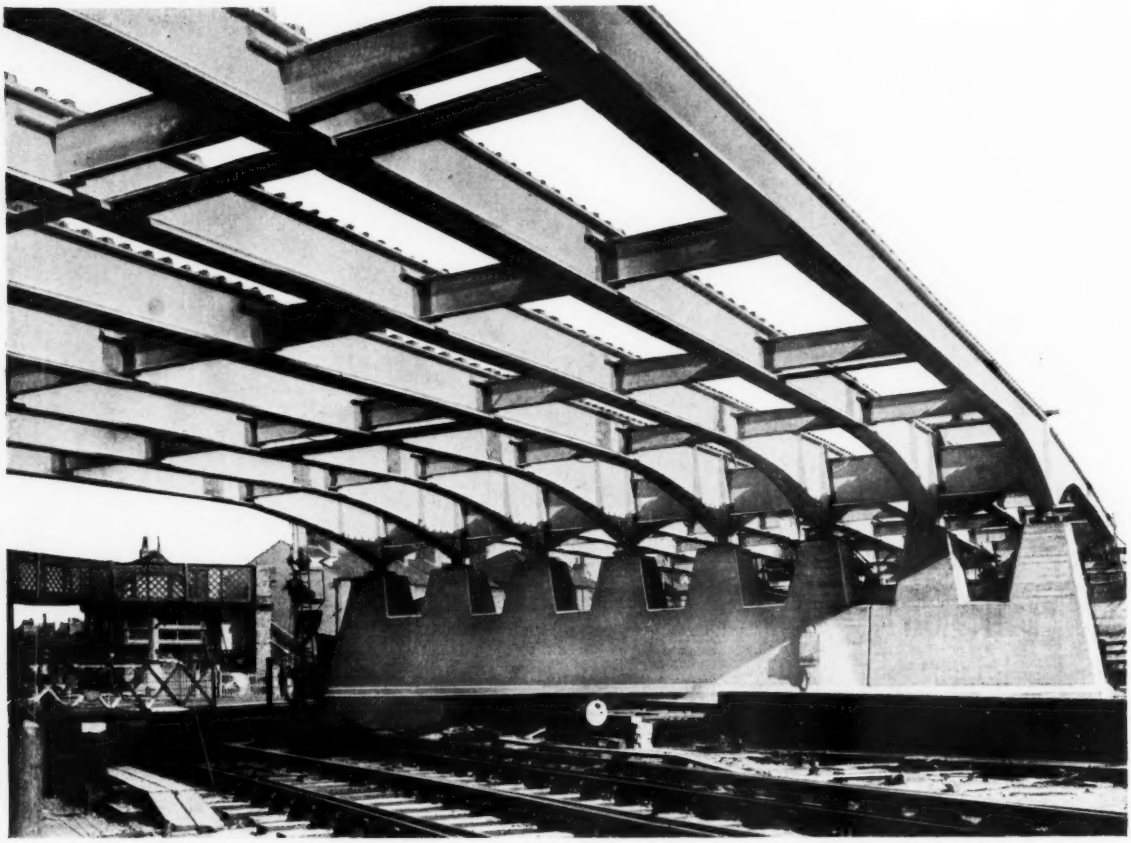

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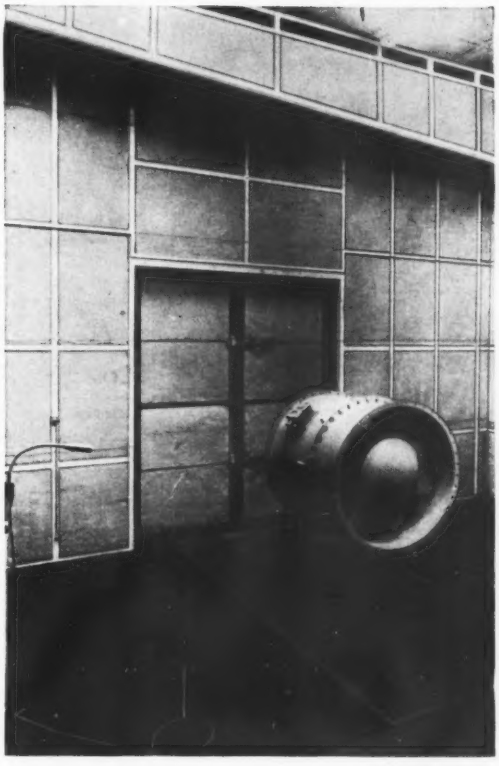

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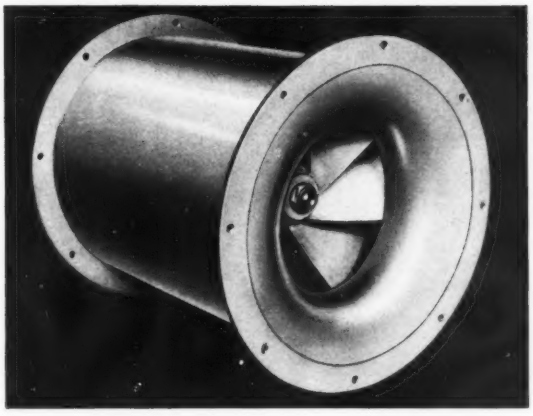

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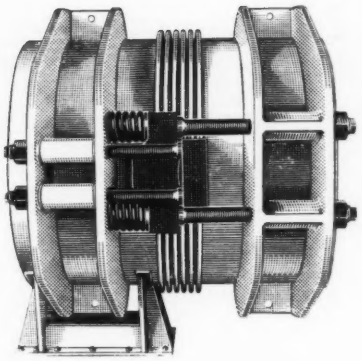

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Vol. 13 No. 129

FEBRUARY, 1959

CONTENTS

PAGE

Concrete Pressure Vessels, by J. Bellier and M. Tourasse 85

Nuclear Chemical Research, by R. Walti .. 90

Australian Uranium—The Mary Kathleen Mine and Mill 92

"Atomic" Amplifier 95

The Advanced Gas Cooled Reactor 96

Some Aspects of the Economics of the U.K. N-Power Programme, by J. C. Duckworth and E. Hywell 98

Accurate Prediction of N-Fuel Life 102

Firm's New "Active" Laboratory 103

Nuclear Developments in Europe, by J. Burkett 104

Nuclearist Writes 108

People in the Nuclear News 109

Nuclear News 110

Machine for Cutting Holes in Curved Surfaces 113

Equipment and Materials 114

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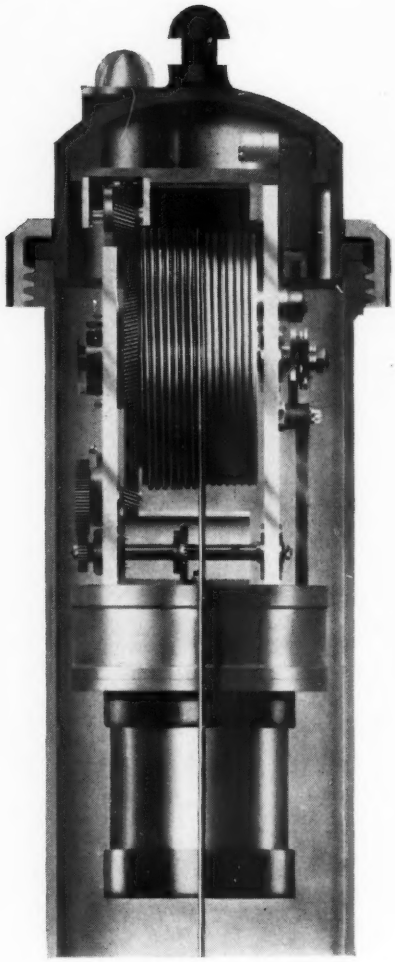

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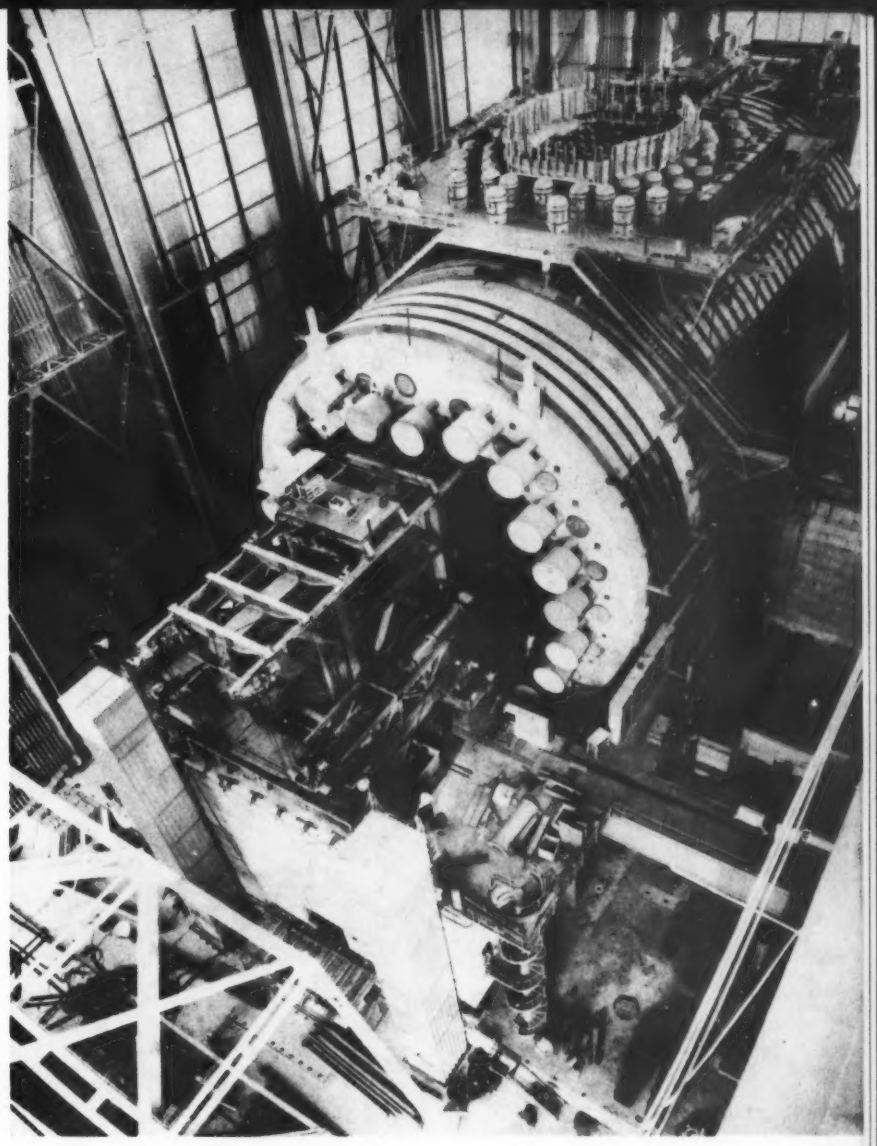

The prestressed concrete pressure vessel for G2 at Marcoule nearing completion

J. BELLIER,
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CONCRETE PRESSURE VESSELS

NOVEL DESIGN AND CONSTRUCTION IN FRENCH REACTORS G2 AND G3

AN unusual feature of the gas-cooled, graphite-moderated plutonium/power producing nuclear reactors G2 and G3, at the French Atomic Energy Establishment, Marcoule, is that the pressure vessels are fabricated in prestressed concrete. By using this material it has been possible to make vessels which not only can withstand high internal pressures — 213.34 lb/sq.in. gauge under normal conditions and 426.7 lb/sq.in. gauge for test purposes— but which are also in themselves biological shields.

In civil engineering design the vessels for the two reactors are identical. They take the form of horizontal cylinders, 46 ft in internal diameter and 59 ft long, closed at each end by a semi-spherical cupola. The walls of the cylinder and cupolas are 10 ft thick. Steel plate lines each vessel to make it gas-tight.

The vessels are mounted, by means of two bearer beams, on rafts. These are basically large sectionalized box slabs, each 197 ft long, 115 ft wide and 29 ft 6 in. high. The spaces between the vertical walls of the rafts house auxiliary reactor plant.

Each unit, in working order and including the additions built on to

the reactor (loading platform, unloading skids, fuel cartridge rupture detection equipment, control machinery, etc.), weighs about 75,000 tons. Materials that went into the construction of each vessel and raft included about 27,500 cu.yd of concrete, 3,000 tons of MS reinforcement (2,500 tons in the raft) and 760 tons of prestressing steel strand (equivalent to 3,100 miles).

Prestressed concrete was chosen for the pressure vessels of G2 and G3 for technical and economic reasons. As in early graphite reactors, the fuel channels are arranged horizontally. At the time of the design of G2 and G3 little was known about the behaviour of vertical fuel elements and it was decided that although the vertical arrangement has distinct advantages over the horizontal system the latter method shoul.l be used. An obvious advantage of the vertical arrangement is that it takes up less ground space. In addition, for the same lattice and uranium loading a vertical system makes it possible to use a pressure vessel of much smaller diameter than that required in the case of horizontal channels. Furthermore, a vertical arrangement leads naturally to a cylindrical reactor, whereas in the horizontal case it is difficult to conceive the reactor being curved or even step-shaped. The main advantage of a horizontal arrangement is that the fuel elements can be handled with ease and simplicity. In addition, to ensure as uniform an irradiation of the cartridges as possible, both for reasons of economy and of homogeneity of the plutonium produced, the displacement of cartridges between the channel inlets and outlets can be allowed for. With the use of prestressed concrete it has been possible to use these advantages and at the same time overcome the constructional problems involved. G2, which went into operation last summer, has a design output of 40 kg of plutonium and 30 MW(e). Design output of G3 is 40 MW(e)

Dam Experience Used

Because of the large dimensions of the vessels and the high pressures which they are expected to withstand, very high prestressing forces are necessary. For ease of execution and reasons of space, separate cables each tensioned to about 1,200 tons, were chosen as the means of providing these forces. The choice of this unit arose from experience gained in the construction of large dams—this had the advantage of working in known territory and of automatically eliminating a number of small unknown quantities.

Consideration of the problem shows immediately that if the step is taken of "storing" the tensile force in the cables in the form of compression in the concrete, it is, in the final upshot, from the steel alone that the bursting strength must come. Nevertheless, this is far removed from the conventional steel structure; neither the steel, its method of use, or the constructional stages of the work and its margins of safety are the same.

Steel is Bundled

The steel is, in fact, high yield strength steel strand. The strands are assembled in large bundles to make up the cables simply by holding them together during handling with strip binders. They are then held in place on the work by anchor blocks, clamps, and by skids and slide-plates, all without recourse to welding with its attendant risks of hidden defects. The steel is prepared for its task of withstanding the pressure stresses by tensioning the strands outside the casing, whilst the elastic elongation, greater than 0.5 per cent., is taken up independently by the prearranged play of tensioning jacks and clamps.

Another feature of this system is that the prestressed steel hoops do not have to be placed and concreted at the same time. Concrete placing, in the absence of heavy strains due to the reinforcement, is fairly rapid, so that access to the inside of the vessel can be made in quite a short time. Thus erection of the reactor inside the vessel can be carried out while prestressing is carried on outside. This overlapping results in an appreciable reduction in construction time.

Finally, it should now be mentioned that with prestressing, and for the normal working stresses of the strands, accidental internal overpressure is only fatal if it reaches a value very much in excess of the working pressure. This results from the properties of the steel used. It will be seen later that, in the case of G2 and G3, at least twice the test pressure, or four times the working pressure, would have to be reached before the vessel would burst.

Damage prejudicial to biological protection would, of course, occur before this point was reached. Doubtless this damage could be repaired, but total rupture would not take place until long after. In other words, the margin of safety is considerable.

Advantage of Prestressing

In the most general terms, prestressing has the advantage that, apart from the secondary effect of the thickness of the walls, the various pressure stresses are opposed by exactly opposite forces provided at will. Whatever may be the distribution of the stresses in the concrete due to the pressure, it is practically certain that they will be balanced, if not exceeded, by the action of the cables. The bursting forces in the cylinder are opposed by the cable hoops, and those tending to push the foundations apart are opposed by straight tension cables. It only remains, then, for matters to be so arranged that the cables cannot break loose, and this is a practical problem presenting no real difficulty.

Building Speed Counted

Apart from the overall dimensions and the various stresses imposed by questions of reactor operation and regulation, the designers of the G2 and G3 pressure vessels had complete freedom in deciding the shape of the vessels and in determining the practical conditions of the prestressing system to the best advantage, and the method of putting them into force. On several points the solution is the result of a more or less straight compromise between advantages and disadvantages, with the preference, other things being equal, going to the solution which made for more rapid construction.

The cylindrical form, approved by those installing the reactor, provided that an internal dihedron was added at the bottom, was adopted by the designers because it enabled prestressing to be carried out by means of hoops as an extrapolation. In the widest sense, this is by means of the technique of prestressed concrete pressure pipelines.

Even so, it was not considered possible to tension the cables in a complete circle, because the consequent overlapping would have brought parasitic transversal forces into play in the casing. Furthermore, the question of anchorage would have been complicated. As it happens, each cable is wound in a plane and does not overlap itself; after making contact with the cylinder

through an angle of about 250°, the cables go off tangentially on either side to be anchored in the bearer beams. More precisely, the cables are anchored, on the one side, in a block lodged in the corresponding bearer beam, and on the other, in a tensioning block set in the longitudinal chamber under the pile and bounded by the bearer beams. Each cable has its tensioning block on the opposite side to that of its neighbour.

The circle is completed by straight cables passing between the spaces left by the hoops, and anchored in the bearer beams.

The question of closing the ends of the cylinder presented a difficult constructional problem on account of its large diameter and the value of the longitudinal forces (slightly above 45,000 tons for the test pressure). It was decided that the strongest arrangement was the spherical cupola hollow side outwards, by which the concrete is in compression.

It is known that vaults in compression—all the more so for cupolas—are practically indestructible so long as their supports will bear. In the present case, a suitable number of hoops identical to those of the cylindrical body (with the same bottom transverse cables) were placed to satisfy the conditions for the pressures envisaged. They balance the radial components of the cupola thrust. The axial components are balanced, from one end to the other, by straight axial cables passing through the circular wall of the cylinder, and which are anchored in the terminal sections of the vessel.

Fuel Openings

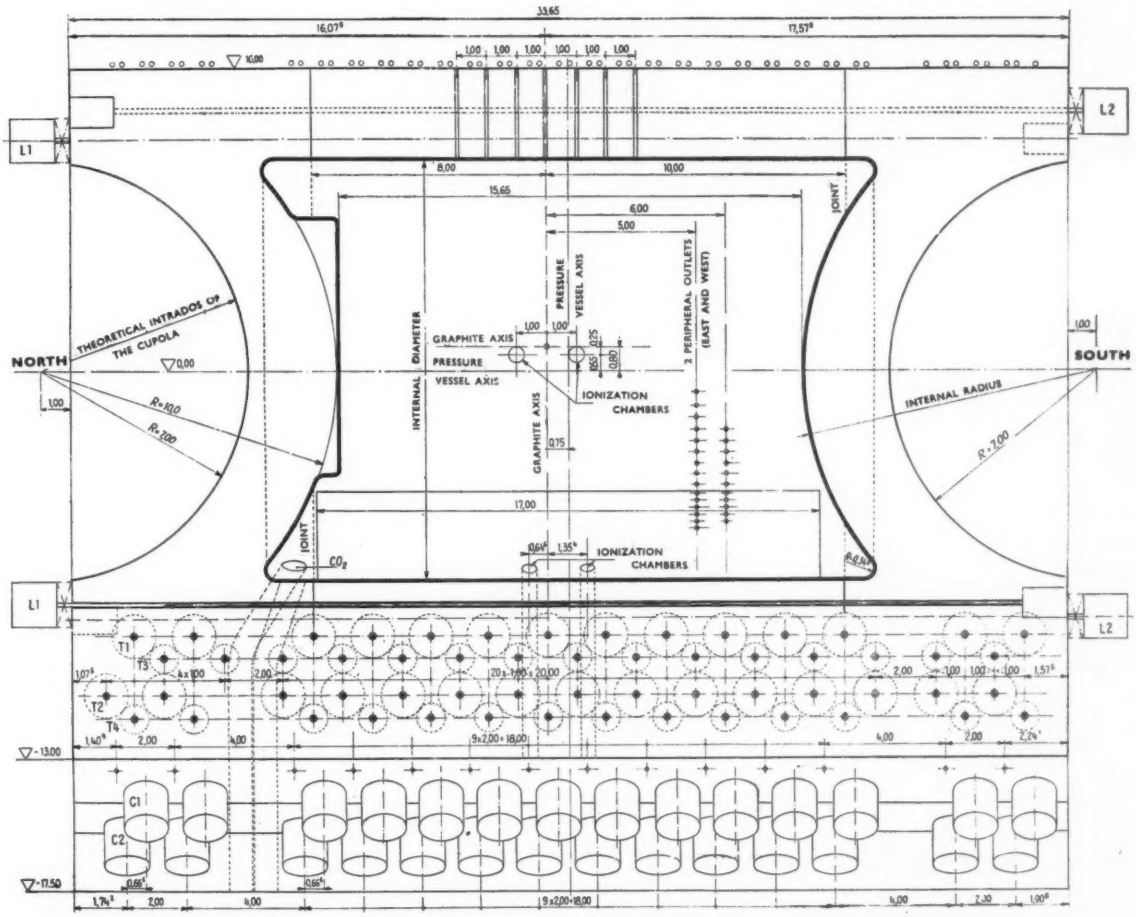
The uranium cartridges are put into the pile through the north end. For this purpose a huge bank of 1,200 steel tubes is incorporated in the cupola, and these tubes correspond to the 1,200 channels of the pile. This bank was precision assembled, partly at works and partly on site, into thick plate headers. After positioning, the spaces between the tubes were filled in with concrete for a length corresponding to the thickness of the theoretical cupola.

The CO_2 Tubes

The tubes extend outwards to thick plate headers, but whereas the spaces are filled in with concrete for reasons of biological protection, the joints are so arranged as to reduce the rigidity of the closure and to prevent it from upsetting the elastic deformations of the cupola proper.

Fourteen 1 m diameter tubes, for the CO_2 supply to the reactor, pass through the south end of the vessel. Biological protection is effected by an independent concrete cover which closes the spherical cavity formed by the intrados of the cupola.

It would have been unwise to rely on the concrete alone for gas-tightness; there would have been no



Longitudinal section of prestressed concrete vessel showing arrangement of transverse prestressing cables

positive guarantee, which was the required condition, that even tiny leaks would not occur. Each vessel was therefore lined inside with continuous steel plate, the separate pieces being welded together on site and anchored in the concrete by numerous rods welded at right angles. It was decided that this lining could, in places, act in some degree as reinforcement to the concrete, especially at the base of the intrados of the cupolas. Additional rods, arranged tangentially, were used to reinforce the anchorage.

Steel Lining Fitted

When the rafts carrying the pressure vessels were finished, the concrete bearer beams and the heavy slab joining them was cast, finishing at the cradle of the reactor proper. The site was then handed over to the boilermakers for them to position and erect the gas-tight lining to the cylindrical body. They also sealed it off and erected a strong internal framework to support it against deformation during the pouring of the concrete.

Concreting was carried out in stages in such a way as to balance the loads and to orient joints with respect to the most probable lines of thrust in the cylindrical body under the action of prestressing and of the internal pressure.

With the internal framework removed and before closing the cylinder with the cupola ends, the heavy and bulky parts of the frame carrying and containing the graphite pile were installed. Then the gas-tight lining to the cupolas was placed, and the latter cast, with the shuttering held in its exact position by a frame incorporated in the concrete. The bank of tubes for loading (north end) was installed in sections carefully positioned in relation to each other and finally fixed by welding to the header plates. Filling in the spaces between the tubes required a smaller aggregate concrete than the rest of the vessel.

Time to Train

Placing and tensioning the bottom straight transverse cables (closing the circle) was done fairly early on, which allowed the specialized crews to be instructed and perfected in this work in the easiest conditions.

On the other hand, placing the axial cables (binding the ends on to the cylindrical body) had to wait for the somewhat late completion of the cupolas. As it was necessary for various reasons to prestress the vessel longitudinally before doing so peripherally, placing and tensioning of the cable hoops also had to wait. However, since the various operations were all carried out without incident and at remarkable speed, there was no delay in completion of the works.

Cable Details

The cables are made up of 5 mm diameter steel strands, with an ultimate stress of the order of 90 tons/sq.in., and an elongation on breaking of at least 3 per cent. on a long length.

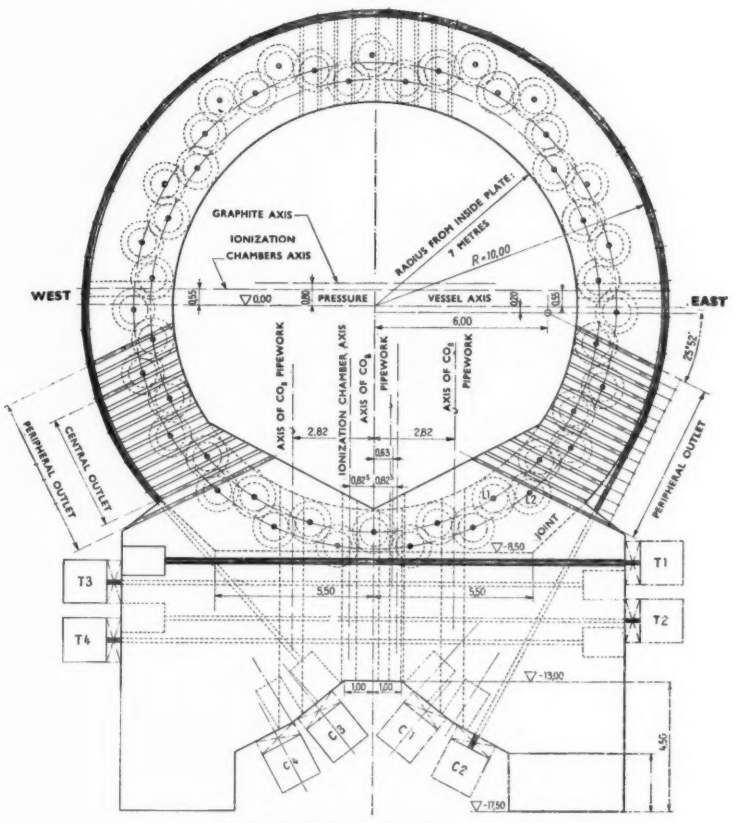
These strands are "self-uncoiling," which means that, delivered in coils (5 ft diameter by about 875 yd), they uncoil into straight strands all on their own as soon as they are freed.

For rapid erection, the cables were fitted with an anchor head at one end, the other being left temporarily free. After being brought up to the vessel, the straight cables were threaded by their free ends into their sheaths, and the hoops placed round the cylinder, and pulled up until the anchor heads came to rest right home in the lodgings prepared in the bearing faces. The anchor heads at the other ends were cast *in situ*, space being left for the tensioning jacks and clamps. Tensioning was effected by pulling on this one end both for the straight cables and for the hoops.

The straight cables are made up of 715 strands, and the hoops of 797 strands, the extra strands in the latter being provided for over-tensioning to make up for friction loss round the cylinder.

The straight cables were brought to the site by a train of trucks, and threaded into their sheaths by means of the overhead crane serving each vessel. They were pulled in by the free end with a winch whose cable was fastened to a bunch of about 20 strands which were longer than the others.

Placing the cable hoops was a more onerous task, because of the double resistance effect due to their weight (they had to be raised from the chamber between the bearer beams



Cross section of prestressed vessel

to the top of the vessel), and to their stiffness opposing bending. This operation was also made more difficult by the greater complexity of the route to be followed. They were drawn up and over by an electric winch, with a second standby winch as a safety measure. The overhead crane was also brought into play to take the weight at certain points.

The tensile force required was provided by 500-ton unit rating oil jacks used in threes. The pressure was supplied by portable electric pumps.

Laboratory Tests

Three jacks forming a group were arranged round the draw heads at equal intervals of 120°. The wedging blocks were located in the spaces. These blocks consisted of hooped concrete wedges of varying height which could be fitted on to each other at will, the final adjustment being made with steel plate wedges.

The load carrying capacity of these concrete blocks was tested in the laboratory. The tests showed that they would stand up to more than three times the load to be imposed upon them in service.

Various precautions, especially previous lubrication, were taken throughout the operations to make sure that all risk of cable corrosion was eliminated both in the present and in the future.

When construction was completed, accessible parts were cleaned and covered with a special protective coating capable of penetrating right between the strands. The inaccessible parts in a sheath, already protected by the initial lubrication, were also maintained in a dry atmosphere. It is also worthy of mention that the possibilities of corrosion are naturally greatly reduced by the fact that the vessels themselves are under cover and that they are also heat producers in relation to ambient air.

Cables Removable

If, however, at some future time, a cable appears to have suffered on any account and is no longer thought trustworthy, it is always possible to withdraw it and replace it. Every cable is, in fact, removable, though in certain cases some masonry filling, not required for construction, but essential for biological protection, would have to be broken out. It is also quite within the bounds of possibility to consider replacing the cables with stronger ones, which would allow the pressure in the vessel to be increased.

To enable the reactor erectors to introduce certain not very large parts into the vessel after completion of concreting, two holes with an area of 3 sq.m were left in the top, their walls being left rough after striking the shuttering. The cables crossing these holes were temporarily omitted.

The holes were not to be filled in until completion of the installation of the pile, that is to say, some time after the great majority of the cables had been tensioned. This presented the risk that the filling-in plug would be " dead," that is, insufficiently prestressed by only the cables crossing

Chamber between the supports of the reactor

it. As regards longitudinal prestressing, this is of very little importance. Peripherally, however, the risk of the plug being blown out by the internal pressure remained. To counter this risk, means were found of prestressing the concrete of the plug in the peripheral sense by dividing the plug into prefabricated parts worked upon by special jacks abandoned in the joint-sealing mortar. Once this mortar had set, the main cables were tensioned.

On account of the size of the works, their original character and the conditions in which they were to be pressure tested, it was considered necessary to make a number of metrological observations during construction and during the tests, and to make arrangements for further measurements to be taken when the pile was in operation.

Head of steel strands that make up a prestressing cable

For this purpose, three measurement networks were established. The first concerned the absolute measurement of deformations in the whole. These were determined by very accurate geodesic measurements made from points round the vessel and in communication with fixed external stations.

Secondly—and more especially with regard to tests—the main relative deformations were measured by means of fixed devices. These deformations were: expansion on the diameter of the cylindrical body; expansion on the diameter of the foundation zone; curvature changes in the cupolas; total elongation between cupolas.

Heat Measurements

Finally, a number of thermometric probes of various types and vibrating cord internal extensometers were buried in the concrete so as to determine the temperature distribution throughout the mass, and the evolution of the stresses in the material.

The remainant tensile force in any cable can be measured at all times by re-installing jacks on its anchor head.

This article is a translation from *Bulletin d'Informations Scientifiques et Techniques* published for the Commissariat a l'Energie Atomique.

Next Month: *Calculations used in the design and construction of the pressure vessels and the prestressing cables for the G2 and G3 reactors will be published.*

N-Chemical Research

Experiences of Swiss Laboratory

by **R. Walti**

Winterthur Technical College

Professor R. Walti

RESEARCH conducted in the chemical laboratory of Sulzer Brothers, Ltd., the Swiss engineering organization, can be divided into three main groups:—

1. Chemical analysis of minerals or sands containing uranium, thorium or zirconium, in order to establish whether the working of Swiss uranium and thorium deposits would be worth while.

2. Extraction of fissile material from minerals: (*a*) Enrichment and isolation of compounds containing fissile materials; (*b*) Extraction of fissile materials from these compounds by reduction.

3. Trace analyses of elements with high neutron absorption cross-section in uranium and other reactor materials.

Uranium occurs in sands partly in the form of uranium oxides soluble in acids or bicarbonates, and partly as inclusions in the mineral zirconium (zirconium silicate), presumably in mixed crystal form. Examination of sands from various parts of Switzerland showed that the soluble component varies considerably.

Separation Process

The insoluble inclusions in the zirconium must be disaggregated. After alkaline attack with caustic soda and sodium nitrate, the silicic acid is separated off by acidulation, the metallic hydroxides—principally iron, aluminium and zirconium hydroxide—are precipitated with ammonia, and the uranium in the form of ammonium diuranate. After conversion into nitrates the uranyl nitrate is separated from the other metallic nitrates by extraction with ethyl acetate from a saturated aqueous solution of aluminium nitrate. By re-extraction of the organic phase with water the uranyl nitrate can be isolated as an aqueous phase.

The microanalysis of uranium is carried out by three different methods, which conveniently supplement each other in respect of sensitivity:—

1. By the fluorescence method (fluorescence of uranyl nitrate in a matrix of sodium fluoride in ultraviolet light), which is suitable for concentrations from 0.2 to 5 parts per million.

2. By the polarographic method (catalytic effect of the uranyl ion on the diffusion of nitrate reduction), embracing concentrations between 5 and 50 parts per million.

3. By the photometric method (photometric evaluation of the uranyl thiocyanate complex at 390 mμ), by which concentrations between 10 and 200 parts per million may be determined, or even much higher contents with appropriate dilution.

Many Sands Tested

A large number of sand and mineral samples from many different regions of Switzerland were tested for their uranium content by these methods. The greater part of these samples showed uranium contents between a few parts per million and 20 parts per million; isolated samples had contents between 20 and 100 parts per million. Uranium contents of more than 1,000 parts per million were attained by the use of enrichment methods on natural sands.

Thorium Present

Materials with considerably higher uranium contents obtained from the tunnels of power station developments were also examined.

Though not itself fissile, thorium is converted by neutron bombardment into the fissile uranium isotope U-233. The determination of the presence of small quantities of thorium in sands was consequently of some interest within the framework of these investigations.

Thorium occurs in sands in the form of inclusions in zirconium crystals. This means that alkaline treatment with caustic soda and sodium nitrate is again required for analysis purposes.

The isolation of the thorium from the other elements occurring in sands is effected by oxalate precipitation from a nitrate solution with the addition of cerium in the form of cerium nitrate as carrier. Separation of thorium from cerium is carried out by extraction of the nitrates absorbed in a saturated aqueous aluminium nitrate solution with tetraethyleneglycol-di-n-butyl-ether.

Photometric Analysis

Microanalysis of thorium is done by photometric evaluation of the reddish-stained complex formed by thorium with 1-(0-arseno-phenylazo)-2-naphthol-3.6-disulphonic acid at a wavelength of 545 mμ. A lower determination limit of 5 parts per million was reached with this method.

The analyses of natural sands in which the uranium content was ascertained often showed thorium contents amounting to two-and-a-half to three times the quantity of uranium.

The interest in determining the presence of zirconium lies in the fact that the mineral might contain uranium or thorium. The determination method consists of the photometric evaluation of the complex formed by pyrocatechin violet and dissolved zirconium which has first been subjected to alkaline disaggregation and evaporation with sulphuric acid, the interfering metallic ions being masked with Complexon III. This method allows zirconium contents down to 5 parts per million to be measured.

Enrichment and extraction tests on some of the sand samples available for the chemical analysis of uranium were carried out. The enrichment tests with uraniferous zirconium were conducted by various methods.

Screen analyses showed that up to 80 per cent. of the uraniferous zirconium occurs in fractions below 0.1 mm grain size. Enrichment according to density differences by means of tetrabromo-ethane or methylene iodide led to tenfold up to almost one hundredfold uranium concentration. The zirconium accumulates at the bottom in these liquids. As this mineral is diamagnetic, it can be separated from the paramagnetic constituents of the sand (e.g., pyrite) by magnetic means, so that the remainder is enriched with uranium.

Plus 100 x Enrichment

A fraction of 95 per cent. zirconium has been obtained with the separator of the Mineralogical Institute of Berne University, which according to the results of our analyses corresponds to more than a hundredfold uranium enrichment. Elutriation and flotation methods of enrichment were not investigated.

The preparation of uranium oxide (U_3O_8) was also studied, mineral samples rich in uranium being used. In these tests the uraniferous mineral was leached out with 5 to 15 per cent. sulphuric acid or 3 to 5 per cent. sodium bicarbonate solution. The aqueous phase containing uranium was extracted with organic solvents such as tributyl phosphate, dodecyl-phosphoric acid or diethyl-hexyl-phosphoric acid, so that the uranium was absorbed in the organic phase and was thus separated from other elements, especially iron.

Water Separation

The re-extraction of the uranium from the organic phase was effected with water. The uranium was precipitated from the aqueous phase with ammonia in the form of ammonium diuranate, dried and calcined to uranium oxide. Uranium can also be separated with ion exchangers.

Tests on the leaching of uraniferous material obtained from tunnels have shown that from 50 to 80 per cent. of the uranium can be leached out, in contrast to the natural sands, in which the greater part is included in the zirconium.

These studies were carried out because, if Swiss uranium deposits are to be worked, the ore will most likely be processed to uranium oxide in the immediate vicinity of the workings. The extraction of the uranium from uranium oxide might conceivably be carried out by plants already in existence or under construction elsewhere.

Trace Analyses

The construction and operation of reactors sets the chemical laboratory the task of working out trace analyses for elements with high neutron absorption cross-section.

The Sulzer chemical laboratory has at its disposal a microanalysis method for boron based on photometric evaluation of the carmine red complex with a detection limit of 0.5 parts per million, and one for the determination of cadmium by photometric evaluation of the complex with dithizone with a detection limit of 1 part per million.

The use of stainless steel in reactor construction demands microanalysis of the undesirable element cobalt, which under neutron bombardment is converted to the highly radioactive isotope Co60. The laboratory has worked out a method with a detection limit of 25 parts per million. Further investigations are being conducted into the determination of hafnium in zirconium, which is employed as a canning material, and the detection of the rare earths, in particular samarium, europium and gadolinium. As chemical analysis presents various difficulties, the endeavour is being made to evolve spectrographic methods for detecting these.

A Welcome Change

In conclusion it may be said that reactor engineering has provided the chemical laboratory with a number of new tasks which make a welcome change from conventional methods of analysis. The principal aim at present is to improve the methods of analysis step by step so as to permit the detection of the very smallest quantities of the elements which may interfere with the operation of a reactor even when present only in traces.

View of the Sulzer Works at Winterthur

Australian Uranium

THE MARY KATHLEEN MINE AND MILL

THE Mary Kathleen uranium mine and ore treatment plant in Queensland, Australia, which was recently officially opened by the Australian prime minister, Mr. Robert Menzies, are expected to produce about 500 tons of uranium oxide a year. This is half the total annual Australian output.

Construction of the mine and plant, which are owned by a company in which the Rio Tinto Group have over half interest, was started in 1956. First oxide was produced in June, 1958.

A Lucky Break

The deposit on which the mine is based was discovered almost by chance. Clem Walton and Norman McConachy, leaders of a syndicate prospecting near Cloncurry in 1954, were travelling along a dry creek bed when their truck broke down. While Walton was repairing it, McConachy left the truck and switched on his geiger counter. It immediately gave high background readings.

Two days later the discovery was confirmed and leases pegged. The deposit was named "Mary Kathleen" in memory of McConachy's wife, who had died a short time before the discovery, and a company, Mary Kathleen Uranium, Ltd., formed to develop it.

A year of extensive geological and metallurgical research followed. It was found that sufficient ore existed to justify a large-scale mining operation and as a result a contract for the supply of £A40m. worth of uranium oxide was signed between the Rio Tinto Mining Company of Australia, Mary Kathleen Uranium, Ltd., and the United Kingdom Atomic Energy Authority.

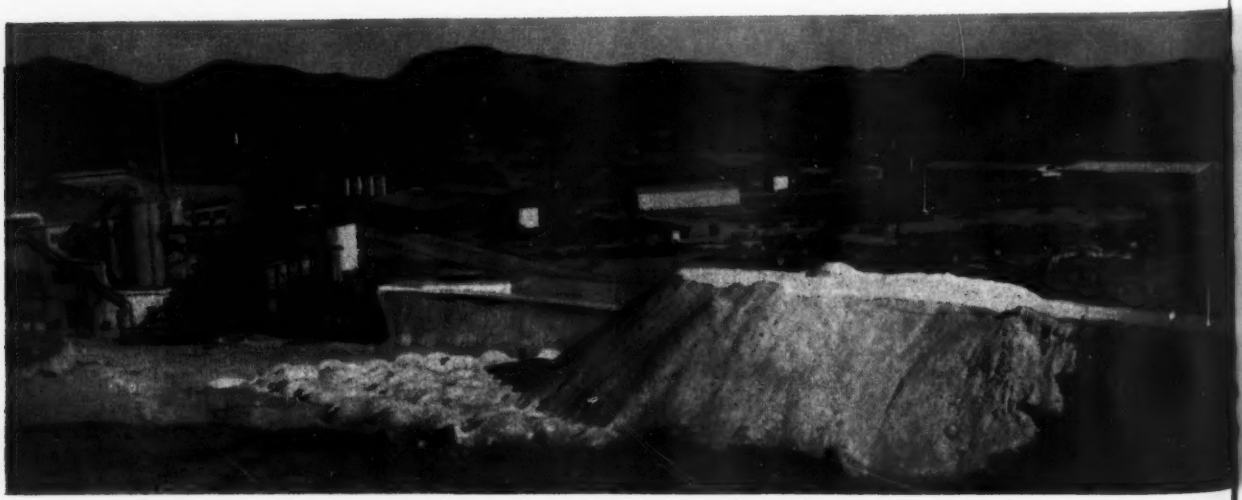
Planning of the mine started in 1955, before it had even been proved that a worthwhile project was ahead. Because the development of the deposit into a mining centre presented unique problems, primarily through its remoteness, it was felt that no time should be wasted in overcoming them.

There were no roads to the deposit and what rail facilities existed were inadequate. The nearest hospital and sources of food supply were at Cloncurry, 45 miles away, and Mount Isa. The only water available was that obtained by sinking wells and it was known that even by this method there was insufficient of it for the needs of a large community and a treatment plant.

All Mod. Cons.

To-day there is a township with housing and facilities for about 1,000 people, including a hospital, school, swimming pool, sports oval, cinema and open-air beer garden. There are also a market garden and orchard for the supply of fresh fruit and vegetables.

A reservoir large enough to provide three years' supply for all purposes



(*Right*) View of the treatment plant at the Mary Kathleen uranium mine. The plant is based on the orthodox acid leach process and conventional equipment and techniques are used throughout. (*Below*) The 300 ft high orebody, which is mined by regular quarrying methods. Open cut operations will enable the deposit to be worked to a further depth of 200 ft

mine ore to a sized $\frac{3}{4}$ in. mill feed. The primary crusher is a 42 in. × 36 in. Jaques Traylor crusher set at 6 in. Secondary crushing from 6 in. to 2 in. is by a $5\frac{1}{2}$ ft Standard Symons Crusher and final crushing to $\frac{3}{4}$ in. by a $5\frac{1}{2}$ ft Short Head Symons Crusher.

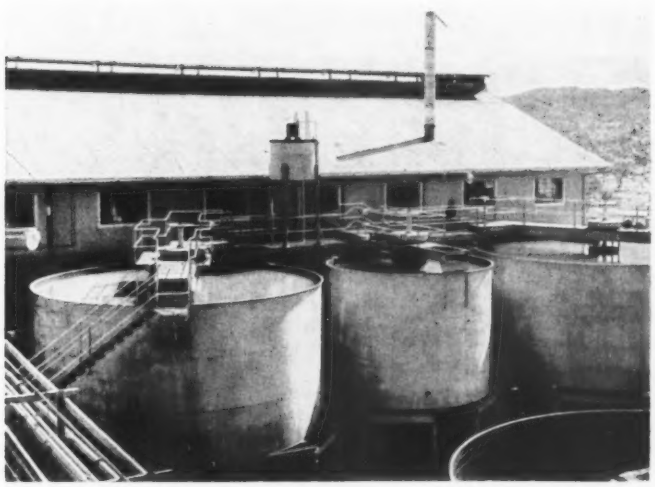
The fine grinding section consists of a two-stage grinding circuit utilizing one rod mill and two ball mills. The rod mill is a 7 × 12 Marcy low discharge mill and operates in open circuit. The ball mills

(*Below*) Precipitation section thickener tanks; (*left to right*) Ion and gypsum precipitate thickener, first uranium concentrate thickener, and final uranium thickener

has been created and a power plant with a generating capacity of over 5 MW built. In addition there is a sulphuric acid plant and facilities for preparing chemicals used in the uranium treatment processing.

The treatment plant is based on the orthodox acid leach process and uses conventional crushing and fine grinding equipment, countercurrent decantation washing, ion exchange solution concentration and alkali precipitation of the uranium. The diagrammatic flow sheet of the plant gives a quick idea of the processing.

The crushing section has a design capacity of 275 tons/hr from run-of-



(*Opposite*) View of the mill showing sulphuric acid plant and sulphur stockpile

are 8 × 8 Marcy overflow mills and operate in closed circuit with 27 in. low pressure cyclones.

Design capacity of the section is 1,000 tons/day from $\frac{3}{4}$ in. feed to a finished product of 70 per cent. —200 mesh.

Finished pulp from the cyclone classifiers is de-watered from 32 per cent. solids to 60 per cent. solids in an 80 ft diameter Dorr torque thickener. The overflow is returned to the grinding circuit head tank for re-use in the milling circuit.

Acid Additions

The thickened underflow is pumped to a rotary distributor which divides the pulp evenly between two parallel banks of four 12 ft × 15 ft turbo-agitators, operating in series. Sulphuric acid is added to each agitator through flow controllers activated by pH recorder controllers to maintain a constant solution pH of 1.7 to 1.8 in all agitators. The acid is added at 50 per cent. strength to avoid temperature increases above a maximum permissible level of 40°C.

An oxidant in the form of ground manganese ore is added, when required, to maintain a Redox potential in the pulp of 400 m.v.

Solids-solution separation and washing are carried out in a five-stage counter-current decantation plant using 75 ft diameter Dorr torque thickeners. These are equipped with VMR6 Dorr diaphragm pumps to control the underflow pulp at 60 per cent. solids.

Wash water, acidified with sulphuric acid to pH 2.0 is added to No. 5 decanter only and the pregnant solution overflows from No. 1 decanter to feed the ion exchange section. Re-pulpers are used between each stage to ensure thorough mixing and Dow separan is added to each stage to promote flocculation and give a clear liquid overflow.

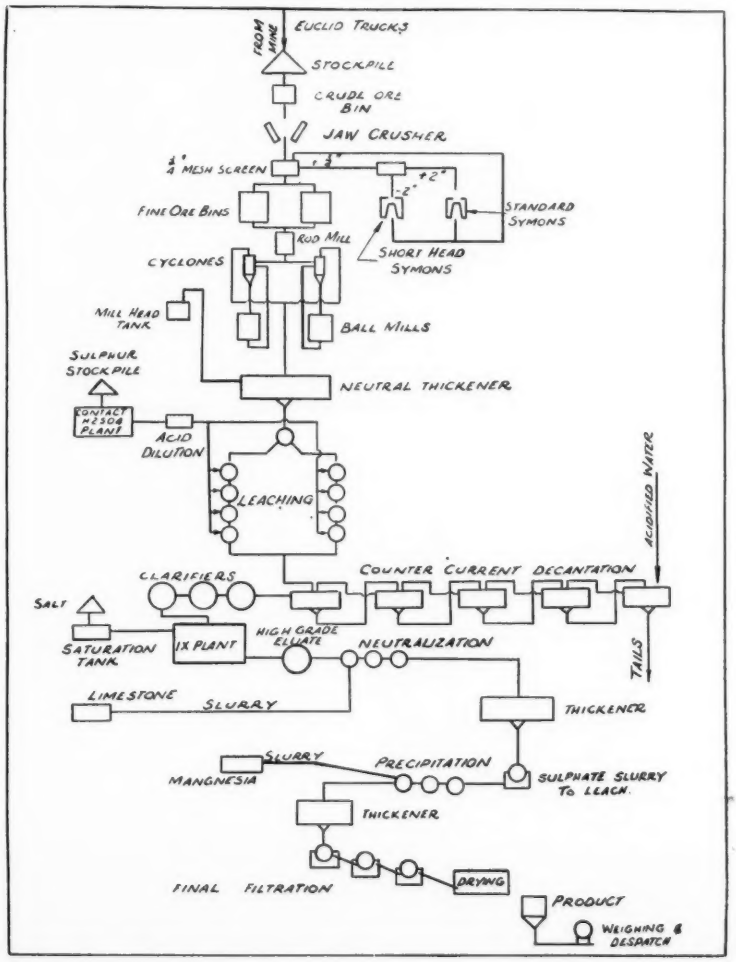
Making It Clear

Clarification to a "gin" clear solution is carried out in two Eimco precoat filters. These have a rated capacity of 200 gal/min and operate at 65 per cent. drum submergence.

Clarified liquor is pumped to a Permutit ion exchange plant equipped with twelve 8 ft diameter, 14 ft high vessels. Arranged in three sets of four, each vessel contains 300 cu.ft

(*Continued on opposite page*)

(*Above*) **Section of the treatment plant seen from the ore stockpiles.** (*From left to right*) **Fine ore and limestone storage bins, grinding station building, mill head tank, neutral thickener** (*behind and below*), **leaching tanks, CCD thickener tanks, ion exchange building, chemical store.** (*Extreme right*) **Part of the power house.** (*Below*) **Flow sheet of the Mary Kathleen treatment plant**



"ATOMIC" AMPLIFIER

A new and special type of gas maser, developed by an American company, which which will remove the noise inherent in electronic devices and thus provide amplification without any extraneous noises whatsoever

THE Industrial Research Division of the Philco Corporation in the United States has recently developed a new and special type of gas maser, known as an " Atomic " Amplifier. This first " Atomic " Amplifier demonstrates unilateral (one-way) gain of microwave energy by means of two electrically isolated cavities connected by a beam of neutral ammonia gas molecules. Energy is transferred from one electromagnetically isolated point to another by the flow of these molecules.

As the oscillating molecules pass through the second cavity, electromagnetic radiation is developed and it appears in the output waveguide. Thus is achieved unilateral amplification without the aid of electronic effects.

The original concept of amplification and oscillation by uncharged molecules through use of a maser was demonstrated by Columbia University in 1955.

Prior to the development of the present " atomic " amplifier, all maser amplifiers were basically bilateral devices and had all the problems of common input-output terminals.

This two-cavity maser research study is part of a pioneering effort in the field of low-noise communication microwave amplifiers and radar systems.

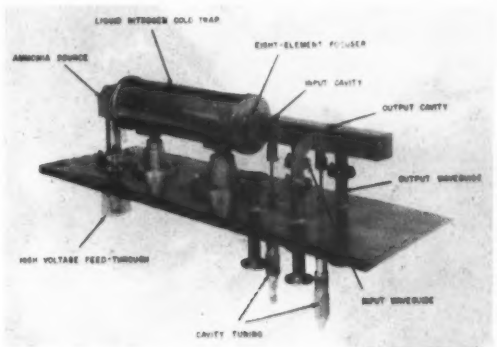
Just as electronics has achieved its greatest versatility and reliability through the inherently unilateral amplifying property of vacuum tubes and transistors, the new unilateral maser promises equally important applications for atomic amplifiers.

Masers remove the noise inherent in conventional electronic devices. They can provide amplification approaching the theoretical limit of no extraneous noise.

It is the noise in an electronic system that produces the static on radio and the white fuzz (snow) on the television screen.

The new " atomic " amplifier also has demonstrated the predicted physical phenomenon of prestimulation of molecules in an excited state. Prestimulation in a two-cavity device promises to provide a greater degree of freedom for controlling the gain-bandwidth properties of the " atomic " amplifier.

The successful operation of masers depends either upon very low noise amplification or very high oscillator stability which represents a dramatic technological " break-through " for electronic components.



Picture shows an overall view of " Atomic " Amplifier, demonstrating unilateral (one-way) gain in microwave energy by means of two electrically isolated cavities connected only by a beam of neutral ammonia gas molecules. As the oscillating molecules pass through the second cavity, electromagnetic radiation is developed and appears in the output waveguide. Thus is achieved unilateral amplification without aid of electronic effects

Australian Uranium

(*Continued from opposite page*)

of synthetic resin. Under normal operations three vessels in each set operate in series on adsorption while the fourth is engaged on the elution cycle. Chloride elution is practised, the barren eluate being brought up to the correct chloride and acid strength by the addition of crude common salt and sulphuric acid.

Precipitation

First stage precipitation of strong eluate solution is carried out in 6 ft × 9 ft 6 in. Pachuca agitators. Finely ground limestone is added to raise the pH of the eluate to a maximum of 3.5 to remove iron and some sulphate as gypsum. The resulting precipitate is thickened, the overflow liquor from the thickening equipment going to the product precipitation section, while the underflow is filtered on a 3 × 4 Eimco rotary vacuum filter. The solids are repulped and returned to the leach circuit and the filtrate is pumped back to the 30 ft thickener feed.

The final precipitation stage is carried out in a bank of three mechanical agitators. The precipitant is finely ground caustic magnesia which is added to produce a pulp of maximum pH of 7.0. The resultant uranium precipitate is thickened in a Warman thickener and filtered on an Eimco rotary drum filter.

Filter Stage

The filter cake is repulped with fresh water and filtered in two stages on 6 ft × 8 ft Eimco filters before being fed to the drying plant.

Filtrate and thickener overflow are pumped to the eluate make-up tank and are re-used in the ion exchange section. Filter media used on all these filters is 12 oz terylene twill.

The washed " yellow cake " precipitate is extruded as $\frac{1}{4}$ in. pellets into an oil-fired continuous conveyor drier, the dried precipitate being packed into 44-gallon drums for shipment.

Among the contractors and suppliers of equipment for the plant were the following: Brush Group (Australia) Pty., Ltd. (four 995 kW generating units and a turbine using steam generated from waste heat from the sulphuric acid plant); Dunlop Rubber Australia, Ltd. (acid resisting rubber lining); Food Machinery (Australia), Ltd. (the Marcy Rod and Ball Mills); Goodyear Tyre & Rubber Co. (Australia), Ltd. (rubber linings for the mill tanks); Jaques Bros., Ltd. (primary jaw crusher); The Permutit Co., Ltd. (ion exchange plant); Simon-Carves (Australia) Pty., Ltd. (sulphuric acid plant); Vacuum Oil Company Pty. (fuel); Vickers Ruwolt Pty., Ltd. (secondary and tertiary Symons cone crushers); and Warman Equipment (NSW) Pty., Ltd. (pumps for slurry handling and the sulphuric acid plant).

The ADVANCED GAS COOLED REACTOR

THE advanced gas-cooled reactor (AGR) the UKAEA is building at Windscale is designed to provide information on and experience of (1) the effects of operation at a high temperature, high pressure, high neutron flux and high burn-up on beryllium-clad uranium oxide fuel elements, (2) the effects of high temperature, high pressure and high neutron flux on the life of the graphite moderator, (3) the compatibility of carbon dioxide at high pressure and temperature with reactor materials generally, and (4) the control aspects of highly rated gas-cooled reactors. The information and experience gained are expected to be available for use in the design of base load stations commissioned after 1965.

A Stage Between

Outgoing steam temperature of the AGR, which will be in operation in 1961, will be in the region of 850°F., 150° more than that of the temperature of outgoing steam from the commercial stations currently under construction and about 160° less than from the planned high temperature gas-cooled reactor. Outlet pressure will be 620-270 lb/sq.in. gauge. Thermal flux will average 1.49×10^{13} n/cm² sec, rising to a maximum of 3.45×10^{13}. Heat output of the reactor will be 100MW and its electrical output 28 MW. Uranium oxide initially enriched by 1.2 per cent. and clad in beryllium will be used as fuel.

The core which is 14 ft high and 15 ft in diameter, contains 250 fuel channels. During the operation of the reactor an increase in the fuel rating will be achieved by reducing the number of channels loaded with fuel elements and increasing the enrichment. Surplus channels will then be blanked off with graphite plugs. The heat exchangers and main gas circulators will be designed to enable this change to take place without the necessity of major modifications being made.

Each fuel channel is provided with its own individual access pipe, thus enabling each channel to be fully instrumented and equipped with its own flow control. Refuelling of a channel can be carried out on load at full gas pressure.

The reactor pressure vessel will be fabricated in mild steel and will have an internal diameter of 21 ft and overall height of about 60 ft. It will be of double shell construction so enabling the inner shell to be cooled by incoming carbon dioxide gas (250° to 325°C.).

Top Control

Refuelling and control of the reactor will be from the top face. Branches are provided in the bottom head of the pressure vessel giving straight-through access and enabling test-loops to be incorporated.

There are four coolant circuits each with a heat exchanger and main circulator. The exchangers will be raised in relation to the reactor itself in order to promote natural circulation of the coolant in the event of a main circulator failure. Since the plant will be purely experimental a single pressure steam cycle will be used with the modest steam conditions of 600 lb/sq.in., 850°F. at the turbine stop valve.

A single turbine coupled with dump condenser facilities will be used for rejecting the full heat output of the plant to forced draught cooling towers.

Contracts Already Placed

Firms with whom the UKAEA have already placed contracts for work on the project include Whessoe Ltd. (reactor vessel); English Electric Ltd. (turbo-alternator and associated equipment); International Combustion Ltd. (heat exchangers); Babcock & Wilcox Ltd. (containment building); Hick Hargreaves Ltd. (dump condenser); Mather & Platt Ltd. (feed pumps); and Whatlings Ltd. (building and civil engineering). Ewbank & Partners Ltd., have been retained as consultants on the turbo-alternators and the steam plant installed in the turbine hall.

Electrical output of the AGR will be 28 MW. Stations based on it will have much larger capacities

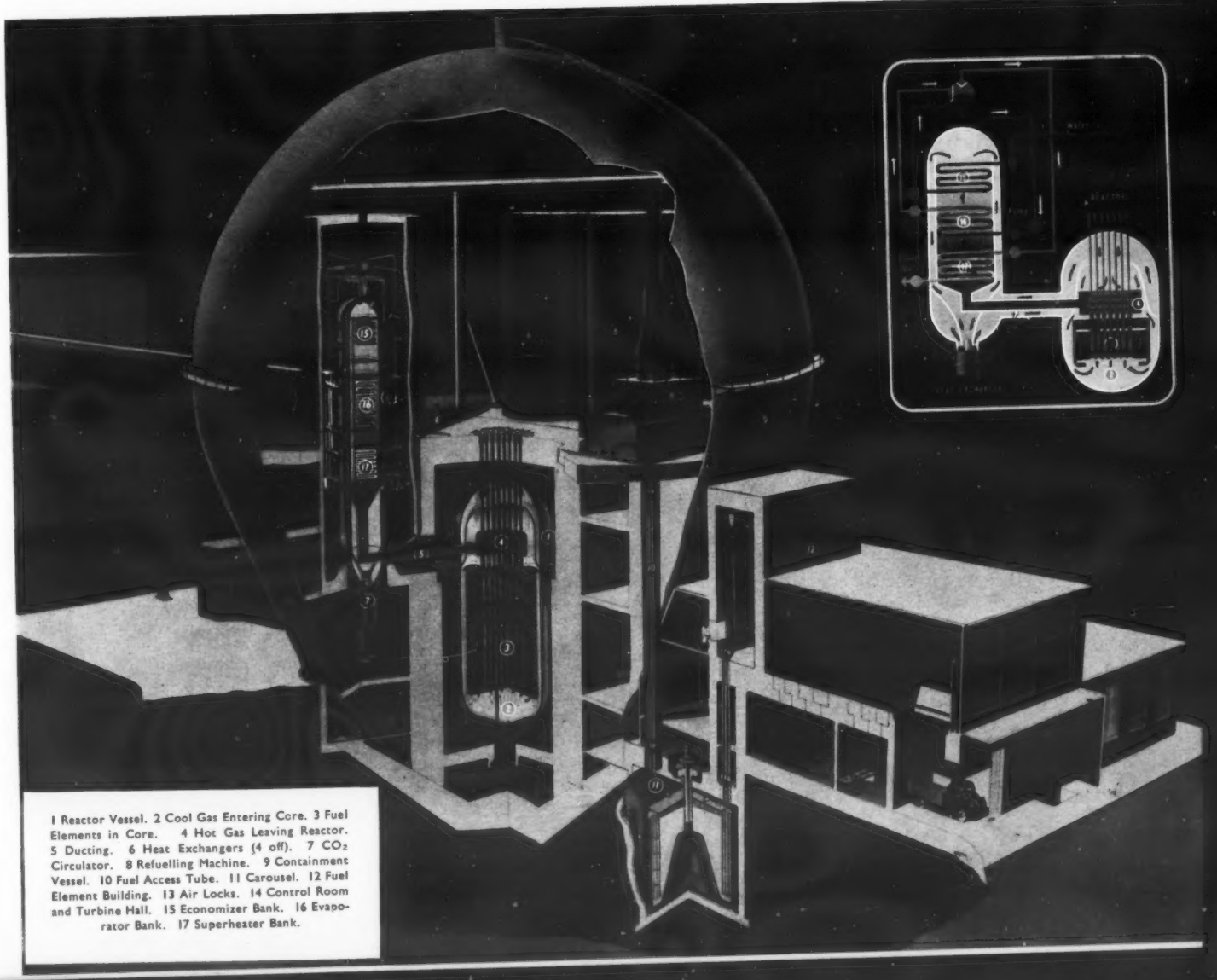
Each fuel channel in the AGR is connected to its own set of instruments and flow control

The reactor and heat exchanger are enclosed in one spherical containment vessel for safety reasons

SECTIONAL DRAWING OF AGR BEING BUILT AT WINDSCALE, CUMB.

THE BASIS OF N-POWER STATIONS IN 1965

A UNITED KINGDOM ATOMIC ENERGY AUTHORITY PROJECT



1 Reactor Vessel. 2 Cool Gas Entering Core. 3 Fuel Elements in Core. 4 Hot Gas Leaving Reactor. 5 Ducting. 6 Heat Exchangers (4 off). 7 CO_2 Circulator. 8 Refuelling Machine. 9 Containment Vessel. 10 Fuel Access Tube. 11 Carousel. 12 Fuel Element Building. 13 Air Locks. 14 Control Room and Turbine Hall. 15 Economizer Bank. 16 Evaporator Bank. 17 Superheater Bank.

Economic Aspects of the U.K. N-Power Programme*

by **J. C. DUCKWORTH,**
Central Electricity Generating Board

and **E. HYWEL JONES,**
South Scotland Electricity Board

THE introduction of nuclear power stations into a large interconnected supply system raises a number of economic and technical problems, some of which have already been discussed, for instance in references [1,2]. In the early stages of a nuclear programme a case can be made out for the installation of a limited number of power reactors on an experimental basis to develop techniques and to gain experience of operation. This phase, however, must necessarily be limited in duration and size, and before a large programme is embarked upon the relative economics of different types of generation must be carefully studied.

Different Criteria

The problem is not a simple one, since amongst other reasons the proportions of capital and running costs in nuclear and conventional stations differ widely, and also the siting criteria are dissimilar. Cost comparisons depend greatly, therefore, on charges on capital, on the cost of transport of conventional fuels, and the degree to which large scale power transfers within the system are practicable. The nuclear generation costs are largely independent of site, since fuel transport costs are low and, as shown later, in the United Kingdom it is evident that for some years they will fall between the upper and lower limits of generation costs from the most modern conventional stations in high and low fuel cost areas.

Under these circumstances a limited introduction of nuclear power stations mainly to carry base loads in high coal areas would promise to be economically desirable. The remainder of this paper is devoted to some comparisons of costs of present and probable future nuclear and conventional plant and to factors affecting the economics of individual nuclear stations and of the system as a whole.

Programme Change

The first statement of a United Kingdom nuclear power programme was made in a Government White Paper[3] published in February, 1955. This envisaged the installation of nuclear plant to give an available electrical capacity of between 1,500 MW and 2,000 MW by 1965, and was based largely on the experience which had been gained in the design of the Calder Hall plant, which had not then been completed.

Early in 1957 the Minister of Power for the United Kingdom made a statement expressing the approval of the Government to an expanded programme by the electricity authorities to provide a nuclear capacity of between 5,000 MW and 6,000 MW by 1965. This reflected both the increased confidence of the Authorities in nuclear power plant as a result of the early operating experience with Calder Hall, and also the advances which had been made by the industrial groups in the design of gas cooled thermal reactors of the Calder Hall type. Later in 1957 capital restrictions made it necessary to slow down this programme slightly, so that the completion of the projected programme would not be achieved for another year, i.e. by 1966. The expanded programme, and the later rephasing are briefly outlined in Government White Papers[4,5].

One of the major changes in the period between issue of the first two papers[3,4] was in the projected electrical output capacity of individual reactor units. The early assumption was that a reasonable extrapolation of Calder Hall experience would lead to a net electrical output per reactor of about 75 MW (150 MW for a two reactor station).

The later studies led to the conclusion that it was both economically favourable and technically feasible roughly to double this size, and as a result the three first stations in the nuclear programme have outputs in the region of 300 MW (from a two reactor station). Further experience and design has led to a continuation of this trend, and without making other than general engineering improvements it has proved possible to design the fourth station in the programme to give a net electrical output of 500 MW.

Fixed Price Contracts

Up to the present time contracts have been placed for four nuclear power stations—at Berkeley in Gloucestershire, Bradwell in Essex, Hunterston in Ayrshire and at Hinkley Point in Somerset. Of these four stations, Hunterston is being built for the South of Scotland Electricity Board and the remainder for the Central Electricity Generating Board, which is responsible for electricity generation and transmission in England and Wales. Details of these stations are shown in Table I.

Each of these stations has been the subject of a fixed price contract (subject to clauses allowing for increases in the prices of materials and labour) and capital charges per

*Paper presented at 2nd International Conference on the Peaceful Uses of Atomic Energy.

Table I.—Details of nuclear power stations under construction in the U.K.

	Berkeley	Bradwell	Hunterston	Hinkley Point
No. of Reactors	2	2	2	2
Total Output Capacity (available to supply system)	275 MW	300 MW	300 MW	500 MW
No. of Turbo-alternators	4	6	6	6
Work started on site	January, 1957	January, 1957	October, 1957	December, 1957
Anticipated completion dates (for full load operation)				
First Reactor	December, 1960	December, 1960	August, 1961	March, 1962
Second Reactor	July, 1961	June, 1961	September, 1962	December, 1962

unit generated can, therefore, be closely estimated assuming a reasonable life of plant and load factor of operation. The capital cost excludes the initial fuel charge but includes (as in conventional stations) the cost of road access, electricity and water supplies off the site itself and of on-and-off-site radiation monitoring equipment, none of which are included in the main station contract, and also an allowance for engineering charges by the purchasing board.

Spent Fuel Problem

Fuel costs for the early nuclear stations are based on an assumed average burn-up of about 3,000 MWD/tonne of the natural uranium metal used. Costs depend on the initial cost/tonne of the fabricated fuel elements and on the value of the spent fuel. The first of these is derived on normal commercial lines, since a straightforward manufacturing process is involved, but the second is more difficult to assess since it depends on the value of plutonium as a fuel in later types of reactor. Since neither reactor type nor the chemical and metallurgical processes involved in the fuel preparation are yet known, it is difficult to assign a realistic value to the irradiated fuel elements. However, it is clear that some value should be credited to this " ash ", and pending the establishment of a true world market price, which may take some years, values are being agreed with the United Kingdom Atomic Energy Authority which are thought to be reasonable.

At the rather low values agreed, the reduction in unit cost due to the irradiated fuel credits form only a minor proportion of the total (about 10 per cent.) and a reasonable error in estimating their value does not, therefore, make a significant difference to the total generation costs.

Even when the costs and values described above are settled the actual computation of fuel costs is not entirely a straightforward matter, since there is not a simple instantaneous fuel throughput as in the case of coal. The original fuel is, in effect, a capital charge, and, during an assumed 20 year life of the reactor, is changed on the average about four times. At the end of its life, the reactor contains its full complement of fuel which has value mainly because of its plutonium content.

Three Stage Costing

In making comparative cost calculations, therefore, it has been decided to calculate the fuel cost in three parts, which for the time being have been taken as:—

(i) Interest on the initial investment in fuel.
(ii) A sinking fund to cover the difference in value between the initial and final fuel complements.
(iii) The cost of fuel replaced.

The first two of these are capital charges and account for about one third of the total fuel cost. The fuel cost for determining " order of merit " of the station (order based on increasing running costs) in the system is, therefore, strictly only the last of the three. Average costs over the life of the plant are worked out by this method, but the most economic approach to the equilibrium cycle and also the " run-down" to shut-down of the plant are themselves complex problems which have not yet been fully worked out, and will differ slightly for different designs. For this reason even average overall fuel costs are not yet exactly known, but can be said to fall within certain fairly narrow limits.

Fair Comparison

To make a fair comparison with conventional power station costs, coal or oil fired stations which will be completed at about the same time as the nuclear plants, must obviously be considered. For this purpose three typical modern stations have been considered, two being based on 200 MW installed turbo-alternators (single-shaft sets) and the other on 550 MW or 600 MW sets (two-shaft), and which represent typical generation costs on high cost and low cost fuel sites.

Of these, No 1 is the first of its kind and therefore carries relatively high development costs. The assumed delivered coal costs for the low cost fuel site and the high fuel cost site range from about 73s./ton to about 93s./ton (11,000 B.t.u./lb).

Interest Allowed for

For both nuclear and coal fired plant the cases of interest rates on borrowed capital of 5 per cent. and 6 per cent. have been illustrated, the former being more appropriate to the situation in the United Kingdom. These correspond to total annual capital charges in the nuclear case (20 years life) of about 8.0 per cent. and 8.7 per cent. and on the conventional plant (plant 25 years life and buildings 40 years) an average of about 6.7 per cent. and 7.5 per cent. respectively.

The overall life of 20 years for nuclear plant is based on what is considered to be a conservative

estimate of the life of the reactor, it being assumed that nuclear technology will have advanced in 20 years to such an extent that neither buildings nor plant will have further use when the reactor is discarded. The life of plant and buildings for conventional plant is that commonly assumed on United Kingdom stations, but is such that the comparison is certainly not weighted in favour of the nuclear plant.

Conservative Estimates

From Table II it will be seen that the generation costs for the first three stations (at 75 per cent. load factor) are marginally greater than those for a modern high-fuel-cost conventional station, and in that respect may be considered to be partially of an experimental nature, the additional small cost being paid to gain experience in technology and operation. In fact, the additional cost may be reduced, or even converted to a saving, either by increases in conventional fuel costs or by operation of the nuclear plants at a higher load factor.

The estimated load factor of 75 per cent. is thought to be a conservative one, and is based entirely on conservative estimates of plant reliability, there being adequate base load on the system to operate these plants (and several more) at 100 per cent. load factor if technically possible. In view of the low fuel costs the nuclear stations will naturally be at the top of the "order of merit" list of stations and will, therefore, be run at the highest load factor which is technically possible.

The generation cost of the Hinkley Point station on the same assumptions is expected to be marginally less than that from a coal-fired station completed at the same time on a site distant from the coal fields. The site of this station, and indeed those for the three previous ones, has, of course, been selected in an area where only high cost coal would be available and the stations will be meeting the base load in such areas, where the choice, in the absence of nuclear power, would have been between local generation with high fuel costs, or generation on the coal field with subsequent transmission of power over high voltage transmission lines.

Life Considered

Certain factors determining nuclear power costs, which may be subject to improvement in future, have already been mentioned—particularly plant availability and useful life. It is anticipated that nuclear plant will have good availability, at least after some experience of operation, and in view of its relatively high capital cost this would improve its competitive position compared with conventionally fuelled plant. It was also mentioned that the assumed useful life of 20 years is thought to be conservative, particularly since the final cause of shutdown is at present uncertain. A brief discussion of this point has been published[6].

In the power stations under construction in the United Kingdom extensive monitoring facilities for graphite, steels and concrete are being provided so that adequate information will be available to determine whether prolonged operation is practicable. At present, however, in the absence of lengthy experience it is not possible to consider longer useful life than that already assumed.

Improvements Wanted

In the immediate future we must consider the possible improvements of the Calder Type reactor. The steady improvement so far has been due partly to general engineering improvements (e.g. better utilization of space and closer optimizing of the whole system) and partly to increases in size consequent upon technical developments such as the ability to weld thicker pressure vessel steel plates with adequate inspection facilities.

Whilst continuing to use magnox canned natural uranium metal fuel, this process is still capable of further

Table II.—Comparison of generating costs between nuclear and conventional coal-fired power stations

	Nuclear Plant				Coal-fired Plant					
	Completion date 1960/61		Completion date 1962		Low Fuel Cost Site				High Fuel Cost Site	
					Station No.1		Station No.3		Station No.2	
Ultimate station capacity	275–300 MW.s.o.		500 MW.s.o.		1,000 MW.I.		1,150 MW.I.		1,000 MW.I.	
Generating set size	–		–		200 MW.I.		550 MW.I. 600 MW.I.		200 MW.I.	
Type of cooling	Direct		Direct		Tower		Tower		Direct	
Year of commissioning first unit of station	1960		1962		1959		1963		1960	
Capital cost (excluding initial fuel) £/kW.s.o.	145		120		55		45		45	
Life of station	20 years		20 years		Plant 25 years Buildings 40 years					
Load factor	75%		75%		75%		75%		75%	
Interest rate	5%	6%	5%	6%	5%	6%	5%	6%	5%	6%
Overall charge on capital	8.0%	8.7%	8.0%	8.7%	6.7%	7.5%	6.7%	7.5%	6.7%	7.5%
Capital charges (including charges on initial fuel)—d/u.s.o.	0.51–0.52	0.55–0.56	0.41–0.42	0.45–0.46	0.14	0.15	0.11	0.12	0.11	0.12
Fuel replacement costs—d/u.s.o.	0.13–0.19	0.13–0.19	0.13–0.19	0.13–0.19	0.37	0.37	0.37	0.37	0.48	0.48
Works operating cost—d/u.s.o.	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total generating costs—d/u.s.o.	0.70–0.77	0.74–0.81	0.59–0.66	0.63–0.70	0.56	0.57	0.53	0.54	0.64	0.65

Table III.—Estimated trend of capital costs of two designs of nuclear power stations expected to be constructed by the CEGB during the period 1961-1970

(Excluding cost of nuclear fuel but including site development and engineering charges)

Design of station	No. of reactors per station	1961		1962-63		1963-64		1965-66		1967-70	
		Capacity	Capital Cost	Capacity	Capital Cost	Capacity	Capital Cost	Capacity	Capital Cost	Capacity	Capital Cost
		MW.s.o.	£/kW	MW.s.o.	£/kW	MW.s.o.	£/kW	MW.s.o.	£/kW	MW.s.o.	£/kW
Present design of graphite moderated reactors using natural or slightly enriched uranium fuel	Twin	300	145	500	120	600	110	700	105	800	100
More highly rated gas-cooled graphite moderated reactor using beryllium canned uranium oxide fuel elements	Single	—	—	—	—	—	—	700	95	800	85
	Twin	—	—	—	—	—	—	1,400	80	1,600	75

development, and it is confidently expected that the capital cost (without initial fuel charge) of £120 per kW of net electrical output for Hinkley Point can be reduced to between £110 and £100 per kW for stations to be completed in 1965-66. This would apply to a twin reactor station, which might have an output capacity in the region of 600-800 MW to achieve this capital cost figure.

Since the fuel costs of such a station would be expected to be the same as for those now under construction, the total generation cost would then lie within the limits of 0.63 pence per unit and 0.58 pence per unit, i.e., about mid-way between the generation costs of conventional plants on high and low cost fuel sites, as previously quoted.

No Alternatives Yet

Alternatives to the gas cooled thermal reactor do not appear to be at all promising in the 1960s. Water cooled reactors are not competitive so long as the electricity supply system does not impose relatively restrictive limitations on the size of individual stations and the load factor available to them. Sodium cooled thermal reactors might be competitive in very large sizes if the technical problems involved were capable of solution in time to compete with gas cooled reactors now being designed.

However, in view of the continued probable improvement of the latter, it seems unlikely that the problems of sodium cooled thermal reactors will be solved in time to render them commercially practicable, at least until the 1970's when the whole field will have to be reviewed in the light of more advanced types (such as the fast reactor) then technically feasible for commercial operation.

The A.G.R.

Throughout the decade from 1960, therefore, the most economic reactor type commercially available would appear to be the gas cooled thermal reactor which will probably take the form of a development of the graphite moderated (Calder) type with a heavy water moderated type as a possible alternative. Detailed consideration has so far been given only to the first of these types, and to achieve the necessary improvement in fuel ratings and gas outlet temperatures (and consequent better steam conditions) new canning materials (possibly beryllium) and probably ceramic fuel in the form of uranium oxide, carbide or cermet would be used.

With graphite as a moderator, slight enrichment of the fuel might be necessary, but the trend of fuel costs is difficult to predict since the high cost of enrichment might be offset by the achievement of higher burn-up. However, capital cost per kW of net electrical output would be expected to fall appreciably and Table III shows the estimated trend of capital costs of two designs of gas cooled thermal reactor stations expected to be constructed for the C.E.G.B. during the period 1961-1970.

The predicted costs for the more highly rated reactors available in the latter half of the period should be regarded as a first estimate of the reductions in capital cost which may well be achieved with this design. It should be noted, however, that the anticipated reduction of capital cost per kilowatt for this highly rated plant will be associated with increased electrical capacity, possibly in the region of 700 MW electrical per reactor. Under these conditions system requirements may make it undesirable to build a twin reactor station, and therefore in Table III costs have also been estimated for single reactor plants. The increased capital cost per kilowatt for the single reactor station is due partly to the fact that ancillaries (such as cooling ponds) cannot then be shared and partly because economies in the spreading of construction costs over two reactors can no longer be realized.

Insignificant

By these dates further improvements will, of course, have reduced generation costs from conventionally fuelled plant, assuming that fuel costs do not rise. These reductions, however, are unlikely to be significant.

On the other hand if the assumption is made that nuclear fuel costs remain constant as development proceeds the reductions in capital costs envisaged by 1970 would indicate that the total nuclear generation cost by then could be as low as 0.45d.-0.5d. per unit sent out, which is likely to be less than the minimum that can be achieved from conventionally fuelled plant operating at 75 per cent. load factor. As previously stated, however, the assumption that nuclear fuel costs will not

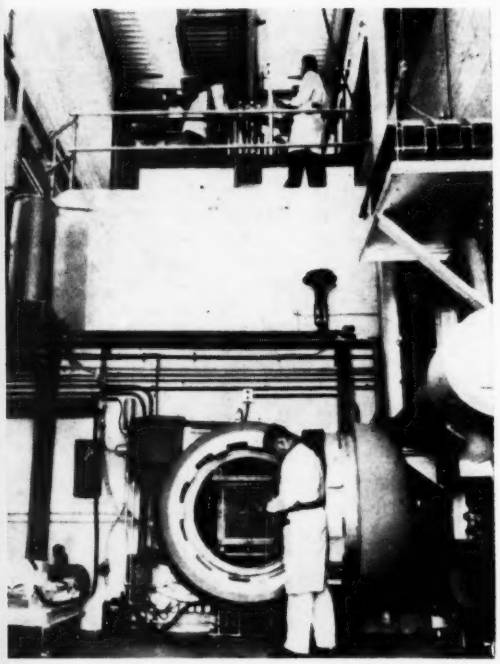
(*Continued on page 112*)

ACCURATE PREDICTION of NUCLEAR FUEL LIFE

AMERICAN COMPANY'S NEW FACILITY

ONE of the nuclear industry's most serious roadblocks is its dependence on theoretical calculations to determine reactor behaviour under actual operating conditions. The Babcock & Wilcox Co., in the United States expects to place this phase of power reactor technology on firmer ground through the use of a combined research and test reactor and "hot exponential" facility in the company's newly created critical experiment laboratory.

The new unit will provide industry with a means of determining accurately how reactor cores will behave at operating temperatures. In the past, reactor behaviour for these conditions has been determined by calculations based on experiments at room temperatures. Now, with this new facility, the first of its kind in the United States, reactor characteristics at high temperatures can be measured.



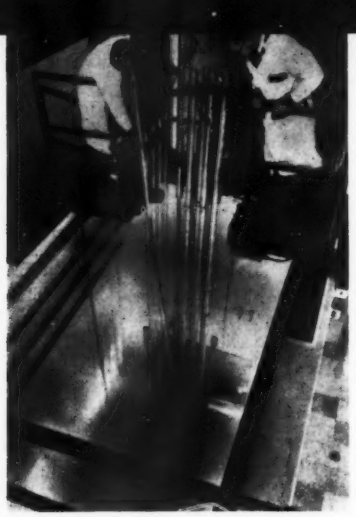
Designed and engineered by physicists and engineering staff of the company's Atomic Energy division, the research reactor will be operated at a normal power of 10 kW. The reactor, however, is capable of powers up to approximately 200 kW. It will serve primarily as a neutron source for tests which will be conducted in the exponential facility. The reactor pool, essentially an open concrete shell 7 ft × 13 ft × 18 ft, will be filled with highly purified, demineralized water. The reactor will also be employed for reactor physics experiments, neutron beam experiments, reactivity testing, and nuclear quality control of materials.

The core, located at the same end of the pool as the exponential facility, will consist of an upright assembly of 16 plate-type elements of uranium-aluminium alloy containing 30 per cent. of enriched uranium.

Speedy Handling

The exponential facility is essentially a pressure vessel, 3 ft in inside diameter by 9 ft long. It is designed to duplicate reactor operating temperature and pressure conditions. A hydraulically-operated, quick-opening door at the outer end permits rapid and frequent access to the test assemblies inside the vessel both for prompt removal of testing equipment and re-arrangement of core assemblies.

Preparing to test the properties of reactor core materials in the B & W critical experiment laboratory. At the top, scientists lower fuel elements into research and test reactor, while below a scientist slides holder of fuel element specimens into pressure vessel of "hot exponential" facility



Removing fuel elements from B & W's research and test reactor

During test operations, a subcritical assembly of fuel rods is placed in the vessel, together with wires which record the neutron distribution along the axis of the fuel rods. The vessel is then filled with water. An external heater and pressurizer produce operating conditions up to 500°F. and 720 lb/sq.in. pressure. The adjacent reactor serves as a neutron source for the test assembly. A boral gate minimizes reactivity coupling between the reactor and the assembly under test.

New Activation System

After the wires have been exposed to neutron bombardment within the assembly, they are removed and their radioactivity is measured on the automatic scanning device to determine both the radial and longitudinal neutron flux distribution throughout the assembly.

Believed to be the first commercial installation of its kind in the nuclear industry, a Teleflex wire activation system, based on a design by the Knolls Atomic Power Laboratory, is a vital part of the exponential facility. Neutron flux measurements at high temperatures and pressures are now possible without the requirement for first lowering the temperature or opening the exponential facility door to remove test material.

The Teleflex system consists of a drive mechanism which directs 8 dysprosium-aluminium wires, .020 in. in diameter and encased in hollow titanium flexible cables, into stainless steel conduits leading into the exponential facility.

Following a predetermined exposure to neutron bombardment from the reactor core, the cables are withdrawn and the exposed wires

(*Continued on opposite page*)

New Active Laboratory

COMPANY'S FACILITY FOR SAFE HANDLING OF RADIOISOTOPES

UNTIL statutory regulations governing the protection of workers in industry against ionizing radiations are brought into being firms using radioactive sources have to make their own safety precautions. It is, of course, in their own interest to ensure adequate safeguards are taken; indeed, it is their moral obligation. It is not surprising, therefore, to find that the measures taken by such firms are of the highest standards and compare favourably with those taken by official organizations.

In Three Parts

A good example of how industry copes with the problem of radiation hazards is provided by Isotope Developments Ltd., who have recently opened a " hot " laboratory at their works at Aldermaston. It is designed primarily for the storage of radioisotopes and the loading up of source containers to be incorporated into the firm's nucleonic products. The laboratory is also used for tracer experiments involving small quantities of " open " sources in liquid and powder form.

The laboratory building, which is constructed of easily decontaminated materials, is in three parts—the reception, the store and the laboratory. Entrance to the store and the laboratory from outside can be made only through the reception area. Here the protective clothing which has to be worn by everybody entering the laboratory is kept. There are also washing facilities.

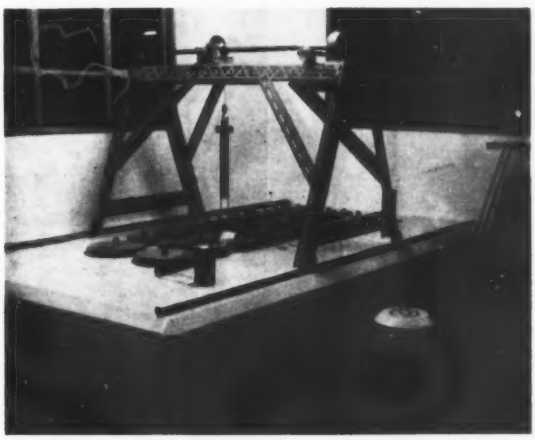
The store is designed to take both gamma and beta radiation sources. The former, which are usually in the form of radiographic capsules, are kept in a series of 2 ft deep holes in a block of barytes concrete. They are kept at the bottom of the holes in aluminium cans which are attached to metal inserts topped by lead plugs.

To remove a source capsule the appropriate insert is raised out of the hole by means of a gantry hoist. The aluminium can is then removed by a pair of long handled tongs and placed in a lead pot for transference to the gamma loading cell in the laboratory section.

Loaded gamma source holders are stored behind a wall of interlocking concrete blocks until required for despatch.

Beta sources, usually in the form of metal foils, are stored in a lead-lined steel cabinet. Before being placed in the cabinet the foils are shielded with perspex or lead or they are stored loaded into a standard IDL source unit.

Loading of the sources takes place in the laboratory. Gamma sources are inserted into holders in a concrete cell by means of remote handling equipment. The interior of the cell is viewed by the operator through either an 8 in. thick lead glass window or a mirror mounted over the top of the cell.



The gamma source storage block. The gantry hoist is used for the removal of individual capsules

Holders and sources are introduced into the cell through a port with a lead lined door across it to absorb radiation scattered from the concrete walls. A radiation alarm is installed to give warning of the presence of the unshielded sources in the cell, so that the door is never inadvertently opened.

Beta sources are loaded in perspex boxes, the operator carrying out his manipulations through port holes, in gloved hands.

Tracer experiments are carried out in a fume cupboard fitted with an extraction fan protected by means of a filter.

An important aspect of the safety precautions is the keeping of records. Details of the nature, activity and location of all sources on the premises and of those despatched to customers are kept.

Predicting Fuel Life

(*Continued from opposite page*)

removed. The wires are then attached to a 27 in. diameter power-driven wheel or " scanning drum." An electronic timer rotates the aluminium drum and causes it to stop for a predetermined time for " counting " purposes. A scintillation detector measures the gamma radiation emitted by the wires. A digital printer translates the impulses either on tape or on an IBM card punch system. Reactor operating test conditions are thus automatically classified for subsequent analysis by nuclear physicists of the company with an electronic computer.

NUCLEAR ENERGY DEVELOPMENT IN Europe

The countries discussed in this month's contribution to the author's series on world nuclear power development all have one thing in common—their electricity consumption is rapidly rising and though present power sources are in no way exhausted, every effort is needed in finding new methods of electricity generation. Of particular interest is the help given to these countries, except Czechoslovakia, by the United States of America who, unlike Great Britain, have made much headway in the development of reactors of suitable size for small countries.

by J. BURKETT

BELGIUM

BELGIUM is one of the most densely populated countries of the world and is highly industrialized. The demand for electricity has increased rapidly. From 1925 to 1955 the annual rate of increase has been 5.4 per cent., and it is estimated that in 20 years time the requirements for electricity will be at least trebled.

Hydro power is practically negligible, 56 MW capacity out of a total 3,548 MW, coal being the only indigenous source of fuel. In 1955 home-produced fuel satisfied 87.5 per cent. of energy requirements. By 1965 this is expected to fall to 73 per cent. The deficiency in energy sources will have to be made good either by increasing fuel imports, particularly oil or by using nuclear power. There has been a large increase since 1956 in coal prices. Belgium has the advantage, however, by the existence of extensive uranium resources in the Belgian Congo although much of this is already committed through bilateral agreements to the U.K. and U.S.A. A representative of CEAN considered that by 1967, nuclear power stations would produce 15 per cent. of Belgium's electric power requirements.

The direction and co-ordination of all nuclear energy activities is the responsibility of the Atomic Energy Commissariat which is also the negotiating body for foreign agreements. The Government is advised on these activities by the National Consultative Commission, whilst the propaganda and information aspects are handled by an association for the peaceful development of nuclear energy.

University Research

Research into fundamental nuclear science is specifically the responsibility of the universities of Louvain, Brussels, Ghent and Liége, co-ordinated through the Inter-University Nuclear Science Institute.

Research into the practical applications of nuclear energy is directed by the Study Centre for the applications of Nuclear Energy (CEAN), which has its premises at MOL.

As far as industrial participation is concerned the two main groups are:—

SEEN—Syndicat d'Etude d'Energie Nucléaire—which in turn created the Société Belge pour l'Industrie Nucléaire (Belgonucléaire) for the purpose of manufacturing and operating nuclear reactors, the manufacture and treatment of fuel elements and the production of radio-isotopes. Belgonucléaire comprises a large number of leading firms in metallurgy, chemical and electrical engineering.

SYCA—Syndicat d'Etude des Centrales Atomiques—a consortium of important electricity producing companies, was formed for the study and creation of atomic power stations. BEN—Bureau d'Etudes Nucléaire—was created to serve as consultant engineers and to co-ordinate all the work necessary to the building of a nuclear power station.

A third syndicate is the Société Co-opérative Electronucléaire with a capital of Fr. 675m.

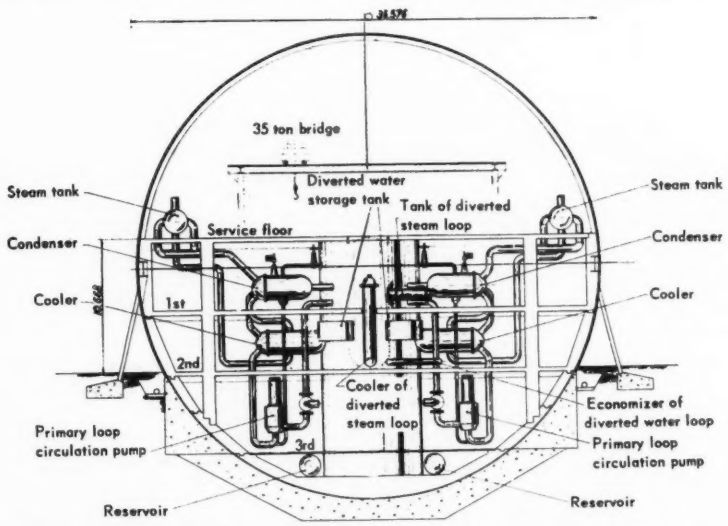
BR 1-2-3

CEAN has been operating at Mol BR-1, a 3 MW natural uranium graphite moderated research reactor since May, 1956. Its laboratory and research staff numbers some 500. The BR-2, a materials testing reactor, is expected to be operating by 1959 with a probable capacity of 25 MW (*see* NUCLEAR ENERGY ENGINEER, August, 1958, pp. 244-7). Its medico-biological research centre will have completed a reactor by the same time. The 1959 programme also includes a 12 MW prototype power reactor, BR-3, built by BEN and Belgonucléaire. It is a pressurized water reactor enriched to 4-5 per cent.

Planned Output

Estimated annual expenditure during the first stage programme is of the order £4m.

Installed nuclear power capacity planned for the future is expected to reach 300 MW by 1963, a further 300 MW by 1967, with 150-200 MW thereafter until 1975. By 1967 it is hoped to have a fast breeder reactor in operation. An agreement has been signed with Power Reactor Development Co. of U.S.A. for exchange of information and services on this type of reactor. Whether the initial reactors are to be of the improved Calder type, the PWR or the BWR, is a decision to be made soon.



Vertical section through the reactor building of the pressurized water reactor BR-3, built by Belgonucleaire and the Bureau d'Etudes Nucleaire

What effect the Euratom programme for nuclear power installations is likely to have on Belgium's national programme is not yet known.

Further details can be obtained from the following papers presented at the 2nd International Conference on the Peaceful Uses of Atomic Energy:—P/1673—The BR-1 pile; P/1679—BR-2; P/416—Belgian thermal reactor BR-3; and P/1801—125 MW boiling water power reactor.

SWITZERLAND

THE primary source of energy is hydro-electric power, coal and oil having to be imported. Power requirements are growing rapidly and to meet these within the next 20 years the remaining hydro-electric potential will be completely developed, coal imports maintained at the present level and oil imports increased considerably. In addition, sufficient nuclear power capacity will have to be installed to produce an annual output of some 6,000m. kWh. Apart from hydro power, because all conventional fuel has to be imported, electric power is expensive and the cost of production is likely to increase. Therefore, the prospect of nuclear power on a competitive basis at a relatively early stage of development seems to hold more promise than in those countries where an indigenous supply of fossil fuels is available.

U.S. Model

Nuclear research work so far has been primarily centred in the reactor A.G., a company formed by a very large number of firms with the Federal Government making a subsidy to meet the company's running expenses. The first research reactor, SAPHIR, is a modification of the Oak Ridge National Laboratory's reactor which was demonstrated at the First Geneva Conference in 1955. During its recent operation research has been carried out on control rod calibration, critical arrangements and flux distribution.

Work in Norway

In the main, the development programme seems to favour the heavy water moderated reactor and the second research reactor which started in June, 1955, will be the first of this type. Heavy water investment is being closely studied and interest has been directed to the possible use of diphenyl as a coolant. Loop tests in SAPHIR will facilitate investigations on erosion effects and heat transfer characteristics.

The Federal Government will also participate in the Halden experiments in Norway.

The Sulzer project for Zurich is also heavy water moderated and cooled. For the purpose of increasing reactivity and reducing the investment cost, the natural uranium fuel element will be enriched to 1 per cent. in U-235.

Under a revised agreement with the U.S.A., 500 kg of U-235 will be made available for research and power reactor purposes. A further agreement with Canada will enable purchase of Canadian uranium.

Apart from Reactor AG, industrial firms who will play their part in the country's development programme are:—

Atomkraft AG, founded in 1956 by Brown-Boveri.

Atomelektra AG, founded in the same year by Elektrowatt AG.

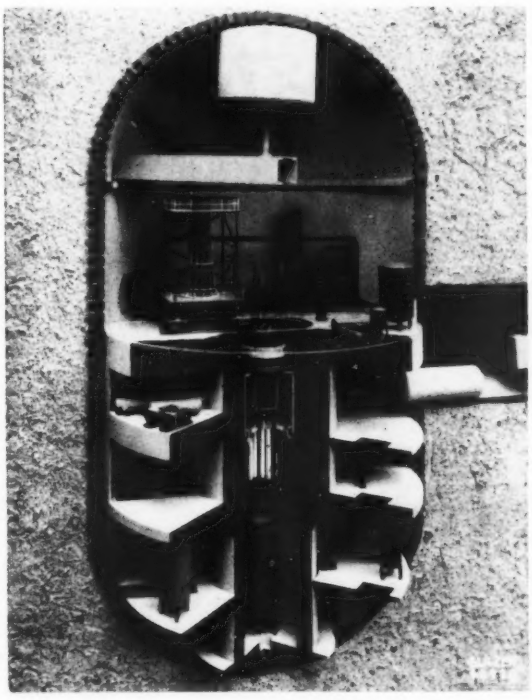
Suisatom AG, formed in June, 1957, by four of the principal electricity undertakings.

Energie Nucléaire SA, a consortium of important firms in French Switzerland.

The Lausanne project which is planned for operation at the 1964 National Exhibition, will provide training facilities for scientists and technicians and serve as a prototype power station.

Further details can be obtained from the following papers presented at the 2nd International Conference on the Peaceful Uses of Atomic Energy:—P/252—Energie Nucléaire S.A.; P/260—Operational experience with SAPHIR; P/246—Sulzer Project—heavy water power reactor; and P/259—Diphenyl cooled, heavy water moderated, natural uranium reactor prototype.

(*Above*) **View of nuclear establishment at Wurenlingen**



(*Left*) **Sectional model of the Sulzer underground reactor project**

AUSTRIA

ALTHOUGH Austria's electric power consumption is nearly four times that of pre-war years, it is unlikely that she will be interested in nuclear power stations within the next ten years.

Of the total production of electricity, hydro power is three times that of thermal power stations, representing only about 22 per cent. of the country's total potential capacity of hydro power resources.

Future projects planned account for 1,040 MW (Westtiroler Kraftwerk) and a 430 MW station (Osttirole Kraftwerk).

As in other countries where conventional power resources are sufficient to meet demands within the near future, although nuclear power is not immediately required, a research programme has been initiated, so that scientists and technicians will have been trained by the time that nuclear power stations are to be opened.

Representing All

The Austrian Atomic Energy Research and Development Co., whose statute was approved in July, 1956, is concerned with training in research, choice of reactors, public health, source materials, etc. It consists of representatives from the Government, private industry, nationalized firms, university facilities and the medical profession. The board of directors is responsible to the Austrian Government, who hold more than 50 per cent. of the shares.

The company's first research reactor will be a 5 MW (heat) " swimming pool " type, costing about £350,000 which will be installed in the proposed research centre near Vienna. One-third of the cost is to be covered by an American grant; the contract

is with the American Machine and Foundry Co. Another research reactor has been planned for one of the universities to be followed by a materials testing reactor and then a prototype nuclear power reactor.

Austria's metallurgical and engineering experience should equip it very well for the nuclear technology of the future. It can produce high-grade steel, aluminium, special metals, pure graphite and chemicals.

CZECHOSLOVAKIA

COMMON with West European countries, the future consumption of electricity is expected to outpace the production of indigenous fuels. The estimated requirement for 1960 is 23,430m. kWh; by 1965 this is expected to be almost double and by 1975 over twice as much again.

Coal alone will not satisfy this increase and even though there is substantial hydro electric potential still under development, it is reported that Czechoslovakia is to make a relatively early start in the use of nuclear power for the generation of electricity.

By 1970 it is hoped to have ten stations with a total capacity of 5,000 MW supplying one-third of all electric power.

Work on the first nuclear power station, a 150 MW(e) natural uranium heavy water moderated reactor near Bohunie, by the River Vah, has started. It is expected to produce partial power by 1960; estimated cost is £50m.

The second station should be operating by 1962.

This country will be very much dependent on Soviet help. Most of the scientists for the Czech. Institute of Nuclear Physics are Moscow trained and the first research reactor, a heterogeneous enriched uranium (10 per cent.) light water type, was supplied by the U.S.S.R.

Czechoslovakia possesses uranium deposits which are mined and shipped to the Soviet Union, paid for at world prices.

Further details can be obtained from the following papers presented at the 2nd International Conference on the Peaceful Uses of Atomic Energy:—P/2091—Research reactor of Czech Academy of Sciences; P/2092—Technical and economic aspects of nuclear power plant building; P/2094—Natural uranium and heavy water reactors; and P/2101—Experimental 10 MW homogeneous reactor—design.

ITALY

ITALY is experiencing a rapidly expanding industrial economy with a corresponding increase in the demand for power. Production figures for electricity in 1956 were 40.5 billion kWh. This will probably reach 76 billion kWh by 1965 and 152 billion kWh by 1975. At the moment over 80 per cent. of this electricity is generated from hydro power which already represents 60 per cent. of the potential resources. At this rate, assuming that the complete potential has been exploited, in 1965 26 billion kWh will have to be provided by steam plant, a figure that will grow to 102 billion by 1975.

Indigenous coal and oil reserves are practically negligible and the local natural gas resources are not available in quantities sufficient to affect the future electric power demands. Coal, which has to be imported, is 50 per cent. more expensive than in other European industrial countries. It is being increasingly replaced by natural gas and fuel oil.

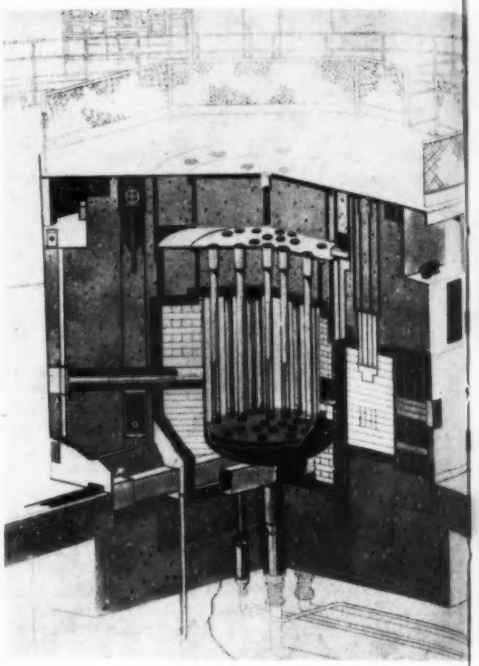
Demand for the latter is likely to rise from 4.6m. tons in 1954 to 13.6m. tons in 1964.

By 1964, Italy's oil imports are likely to endanger the balance of payments—possibly of the order of nearly $500m. per annum—thus making the exploitation of nuclear power an urgent matter. Italy is likely to be among the first countries where electricity from nuclear power will be produced at a competitive price.

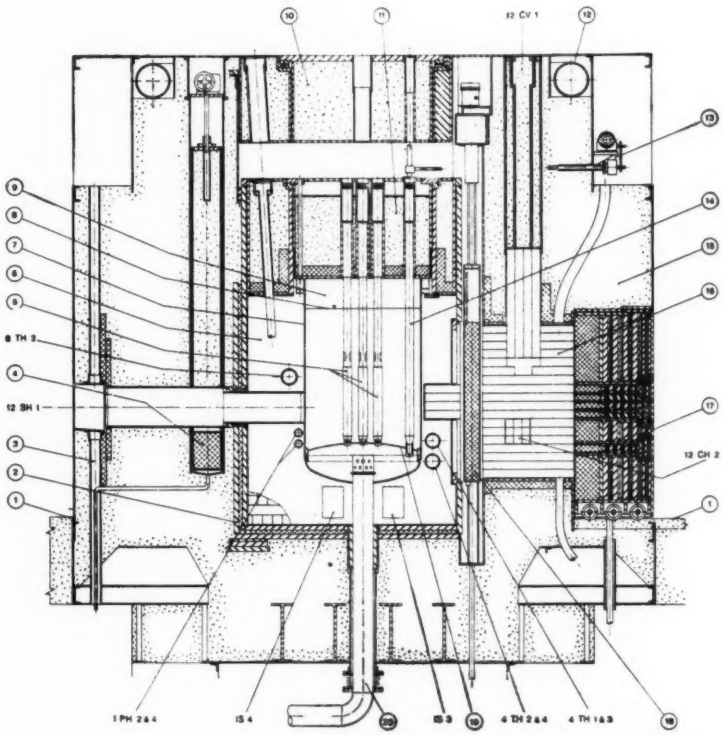
Concentration in the South

Total nuclear power capacity necessary by 1965-67 has been estimated at 3,000 MW. It is hoped that this will provide 13,900m. kWh by 1965. By 1970 nuclear power might contribute 20,000m. kWh towards the nation's total requirements, increasing to 27,000m. by 1975. The greatest effort will be devoted to developing the South, a factor which will most likely demand preferential treatment in capital investment for that part of Italy.

Original research was started in 1946 by CISE (Centre of Information, Study and Experiment), an organization founded by



Sectional drawing of ISPRA



The 5 MW heavy water reactor ISPRA supplied by ACF Industries, of Washington, to the Italian National Committee on Nuclear Research

Key:—1 Operating floor; 2 Thermal shield; 3 Utility pipe; 4 Vertical shutter; 5 Fuel elements; 6 Graphite reflector; 7 Main D_2O tank; 8 D_2O level; 9 Helium; 10 Rotary plug; 11 Lower top lid; 12 Emergency D_2O tank; 13 Fine control rod drive motor; 14 Fine control rod; 15 Biological shield; 16 Thermal column; 17 Thermal column door; 18 Thermal column shutter; 19 Pressure plenum; 20 D_2O inlet

private power companies with the collaboration of CNRN, the National Committee for Nuclear Research, and the Milan Polytechnic. Since then CNRN has withdrawn its support.

CNRN is supervised by the Ministry of Industry and Commerce and acts as technical consultant to the government in promoting and co-ordinating fundamental and applied research at its own centre at Ispra and the work of universities and other establishments. Its scientific and technical staff will number some 600 when research facilities are fully developed. Its main facility is the CP-5 type research reactor designed by ACF-Nuclear Products, and a 1,000 MeV synchrotron at Frascati.

Research and experimentation is also being pursued by a private company, SORIN, jointly owned by Fiat and the Montecatini Groups. It will have a swimming pool reactor and laboratories for chemistry, physics and metallurgy.

Fuel from U.S.A.

SELNI (Societa Elettronucleare Italiana), which was founded primarily by the Edison-Volta group, who hold 55 per cent. of the interests. are interested in acquiring a pressurized water reactor of the "Yankee" type from Westinghouse because of its smaller capital investment. Enriched fuel will be assured through the U.S.A. agreement which assures the supply of 7,000 kg U-235 for research and power developments.

SORIN (Societa Ricerche Impianti Nucleari), founded in 1956 by the Fiat and Montecatini groups, will provide power for use by the two partners, particularly the latter. Apart from the research facilities already mentioned, the company is considering a 200 MW Calder type and a 130-140 MW PWR.

The first stage in Italy's development programme will not be completed until 1962, at least, and because the electrical and manufacturing industry is not yet equipped to offer nuclear power plant, foreign firms will play a large part in taking the country to the second development stage when 3,000 MW is the forecasted capacity.

The provision of Italy's first nuclear power stations is in the hands of a number of companies specially created for the purpose by large power groups, several of which are privately owned, the remainder being state corporations. AGIP Nucleare, which has recently concluded an agreement with the Nuclear Power Plant Co. of Knutsford in Cheshire for the construction of a 200 MW Calder type reactor, was set up by the state corporation ENI which is primarily responsible for the exploitation and distribution of Italy's natural gas resources.

Naples Reactor

SIMEA (Societa Italiana Meridionale Energia Atomica) was formed by AGIP and another state-owned corporation, Instituto Ricostruzione Industriale (75 per cent. and 25 per cent. shares respectively) to acquire a pressurized-water reactor from Vitro Corporation of New York. This is to be sited near Naples.

SENN (Societa Elettronucleare Nazionale) is predominantly controlled by the IRI power group Finelettrica, who have 85 per cent. of the shares. This company has been chosen to construct the nuclear power plant for the World Bank scheme. The International Bank for Reconstruction and Development), whose aims are to assist the economic development of its member countries, are particularly interested in the economic operation of nuclear power plants. Italy was chosen for the Bank's initial experiment because it had the necessary limiting factors: shortage of natural fuels and conditions for a nuclear plant to be economically competitive. The outcome of the project, ENSI (Nuclear Energy for Southern Italy), is likely to influence future investment not only of the World Bank but also the programmes of other countries with similar conditions. The project is under the supervision of distinguished nuclear specialists from other countries.

Further details can be obtained from the following papers presented at the 2nd International Conference on the Peaceful Uses of Atomic Energy:—P/1363—Nuclear power programme; P/1364—The SENN nuclear power plant project; P/1120—Project ENSI —large nuclear power plant in Southern Italy; and P/1383—ISPRA research reactor.

SPAIN

SPAIN'S industrialization is proceeding rapidly, consumption of electricity has likewise increased; at the high rate of 8.5 per cent. a year. The country is poor in fossil fuels, hydro power being the primary source of electricity generation. In 1956 this accounted for 79 per cent. of the total production. It is estimated that the potential hydro-electric power which is four times existing capacity, will have been completely harnessed within ten years. There is a need therefore for nuclear power in the near future. The installation of 350 MW is envisaged by 1970, increasing to between 21,000 and 39,000 MW by the year 2000.

The Spanish Nuclear Energy Board has been entrusted with all research and development work. Experimental facilities will include a 3 MW (heat) "swimming pool" type reactor for operation in 1958, supplied by International General Electric. Government approval is awaited for a materials testing reactor and a 20 MW(e) reactor.

Two N-Groups

Industrial participation is assured through two consortia, TECNATOM and NUCLENOR (Centrales Nucleares del Norte). The former is composed of a number of leading power and industrial firms together with the Banco Urquijo. The latter has been founded by two large electricity undertakings, Iberduero and Electra de Viesgo. This company will concentrate on providing nuclear power to the highly-industrialized Bilboa region. Approval has been given by the Spanish government for the NUCLENOR to build a nuclear power station. This will possibly have two units of 220-250 MW(e) capacity each giving an estimated output of 1,750 kWh per annum. The first unit might be operating by 1965.

As a long-term project, a 132 MW plant may be installed near Puerto Santa Maria, in connection with a new steel works planned by Siderurjica de Sur.

PORTUGAL

PORTUGAL has witnessed a rapid turnover since 1950 from coal-fired power stations to hydro power. From 1931 to 1950 hydro-electric generation provided 38.4 per cent. of the total demand but during the next five years this increased to 85.3 per cent. There is sufficient potential hydro power to last up to 1975. Indigenous coal is of poor quality and has no great reserve but new thermal stations, designed to supplement hydro power during years of low flow, will use this coal.

It will be some time before nuclear power can compete in price with hydro-electric generation. Whilst a new source of energy is not needed before 1975, because of the operational experience that is required, the first nuclear power station should be operating by 1965. Portugal is fortunate in having a comparatively large reserve of uranium.

The Portuguese Nuclear Energy Board is responsible for research and for the co-ordination of all developments. Its research centre will be equipped with an A.M.F. Atomics 1 MW "swimming pool" reactor and a pilot separation plant.

Further details can be obtained from the following papers presented at the 2nd International Conference on the Peaceful Uses of Atomic Energy:—P/1822—Problem of electric energy in Portugal, role of nuclear power; and P/1824—Some results of uranium prospecting in Portugal.

BOOK REVIEW

Dictionary of Nuclear Science and Technology. In six languages. Edited by W. E. Clason. Size 9¼ in. × 6 in. × 914 pp. Price £7. Published by the Elsevier Publishing Co.

This is the fourth in a series of scientific dictionaries in six languages. Over 4,000 nuclear and radiation terms are contained in the basic list, which gives the definition of each word in English, together with the equivalent term in French, German, Spanish, Italian and Dutch. Each entry is numbered so as to enable cross references to be made from the alphabetical lists in each language given at the back of the book. The definitions, which are based on international standards, are precise and concise. Sometimes they are too pedantic, as far instance in the case of zeunirite. Could not this have been defined simply as a mineral containing uranium and copper as was done in the case of the allied mineral torbenite? Of course, perhaps the editor was having a little joke when he defined it as "a copperbisuranylorthoarsenate"! Mere quibbling, apart, this dictionary, with its simple practical layout, is a valuable reference book which should find its way on to the bookshelves of many a nuclear scientist.

'NUCLEARIST' writes . . .

SOME weeks ago, when the spirit of Christmas was still in the air I happened to be talking of toys to a colleague of mine. He remarked that he was surprised that nobody had yet marketed a toy nuclear power station. My reply was that I had seen in Britain many "atomic" submarines, ships, planes, and guns, but that I thought the idea he mentioned would be much more likely to appear first in Germany. Imagine my surprise when I read later that a model nuclear power station, complete with concrete biological shield, heat exchanger, and cooling tower, had been placed on the market by Wilhelm Schröder, of Ludenscheid. It is available in this country too!

* * *

Insertion or withdrawal of the control rods adjusts the current in the electrical fuel elements, the heat being transferred to water in the heat exchangers. Steam is raised, passed to the cylinder, and an engine is brought into operation. I almost wish I could have been a youngster lucky enough to have found one of these toys in his Christmas stocking.

* * *

Most industrialists have been able to look upon nuclear energy as a sort of Santa Claus who brings them toys, in the form of isotopes, for the solution of their many problems. What looks like the first rebellion against this particular Santa, however, comes from Duren, in North-Rhine Westphalia, a centre of the photographic industry. Manufacturers there are protesting that the nuclear centre at nearby Stetternich may ruin their business, since photographic films and plates are highly sensitive to radiations. Undoubtedly, should there occur any widespread sacrifice of the sensitive products, there will be a case for litigation.

* * *

Sensitive films have also been in the headlines on the other side of the Atlantic. Nearly all persons working in nuclear establishments or with radioactive materials have insufficient exposure to appreciably affect the conventional film badge. Since such a film measures normally only those exposures exceeding 20mr, the latter is normally assumed to have been received each week. This automatically makes an assumed annual dose of one roentgen, or 20 per cent. of the maximum permissible dose. It is hardly surprising, then, that this assumption, and the degree of uncertainty which it involves, are the cause of some anxiety.

Tracerlab, of Massachusetts, have now introduced a twin-film to cope with this difficulty. In addition to the usual weekly film, users carry another film which is exposed for 13 weeks, thus reducing the assumed minimum exposure to 0.077r/year. Over the last ten years, the annual maximum permissible exposure has been reduced from 26 to 5r, and in view of the uncertainty about the threshold dose for radiation damage, the closer the watch which can be kept on the small doses, the greater will be the degree of assurance that all is well.

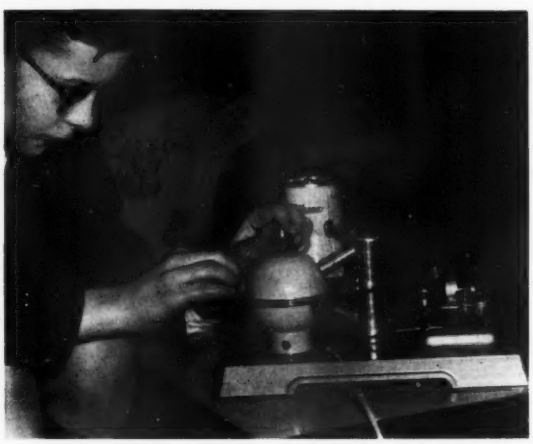
* * *

Radiation exposure as a result of fall-out still continues to afford plenty of scope for conflicting opinions. German observers in Mainz and Freiburg are very doubtful of the dangers to humanity arising from the nuclear devices which have so far been detonated. In one week in Berlin only 12 radioactive particles were recorded, and the presence of cobalt-60 was not confirmed. On the other hand, the activity found in the antlers of reindeer, after the most recent series of Russian nuclear tests, has been high enough to cause concern in Sweden. Similar disconcertingly high activities have been recorded in various materials from many parts of the world.

Although governments have assured their peoples that the radioactivity from nuclear tests has never presented any hazard, the growing peaceful applications of nuclear energy will obviously bring some danger in their train. Megaton bombs may be harmless, of course, but research—and power-reactors springing up like mushrooms all over the world demand vigilance. It is consoling, then to know that a world-wide civil defence organization has been set up. With Professor Albert Jentzer at its head, this body will be centred at Geneva. Observations from a huge network of detecting stations will be fed to the centre for statistical analysis, and there, too, will be a catalogue of the nuclear research centres, nuclear power stations and isotope separation plants of the world. I wonder how far the Iron Curtain countries will be willing to go in divulging their secrets in order to assist in this work.

* * *

One cannot help applauding the little men of Nippon! When the Americans supplied enriched uranium fuel for the Japanese research reactor, one condition was that the spent fuel should be returned for reprocessing to the U.S.A. This, of course, was quite reasonable, but it meant loss of a heaven-sent opportunity for the Japs to obtain experience of fuels and their processing. The little Asiatics, however, obviously piqued, have now made the Americans agree that the plutonium returned to the U.S.A. shall not be used for military purposes.



Nuclear engineer of the future? A boy plays with the German made toy nuclear steam generating plant available in Britain at A. W. Gamage Ltd., of Holborn

PEOPLE... in the NUCLEAR NEWS

Awarded the OBE in the 1959 New Year's Honours List were **MR. PAUL T. FLETCHER,** director of engineering of the UKAEA Industrial Group, Risley, and **MR. PETER W. MUMMERY,** head of the power reactor branch, reactor division of the UKAEA, Harwell. Recipients of the MBE included **MR. IAN HENRY HOGG,** who is in charge of the planning and organization side of the Research and Development Section of UKAEA, and **MR. FREDERICK STEPHEN DENNARD,** a charge hand working on the control of ceramic powders preparations at the AWRE, Aldermaston. **MR. SIDNEY H. C. BELL,** charge hand carpenter at AWRE, Foulness, was awarded the British Empire Medal.

New controller of the East Midlands division of the Central Electricity Generating Board is **MR. O. S. WOODS,** AMIMechE, AMIEE, formerly chief generation engineer (operation) of the division. Mr. Woods was first apprenticed to switchgear manufacturers and then served five years training with the British Thomson-Houston company at Rugby. In 1934 he took up an appointment at Battersea power station and six years later joined the London Passenger Transport Board as personal technical assistant to the chief engineer, subsequently becoming assistant resident engineer at the board's Neasden power station. In 1944 he obtained a similar position at the Ironbridge power station of the West Midlands Joint Electricity Authority and later became resident engineer at the Barton power station of the Manchester Corporation electricity department. In 1948, Mr. Woods joined the North Western Division of the former British Electricity Authority as generation engineer (operation) and three years later was appointed to the East Midlands Division.

MR. G. C. R. ELEY, CBE, has joined the board of The British Oxygen Co., Ltd.

Appointed as assistant manager of the Babcock & Wilcox mechanical handling division, **MR. J. H. PRICE** has for many years been closely associated with the design and supply of Babcock ash and dust handling equipment. More recently he has been concerned with the expansion of the mechanical handling division's activities into the ore, phosphates and chemical products fields.

MR. A. P. M. PURDON has been appointed operations study manager in charge of central operational research and work study for the British Oxygen Co., Ltd.

MR. J. N. TOOTHILL, CBE, FCWA, CompIEE, CompBritIRE, FRSE, has today been made a director of Ferranti Ltd. He joined Ferranti in 1935 as chief cost accountant, and was appointed general manager of the Edinburgh factory in 1942, which position he still holds. Mr. Toothill has been closely associated with the company's activities in the electronic field, and was awarded the CBE in 1955. Mr. Toothill is a vice-president of the Scottish Council (Development and Industry) and chairman of the Finance and Research committees.

Recent appointments in the John Thompson group of companies feature directorships of John Thompson (Wolverhampton) Ltd., for **MR. J. R. THOMAS** and **COMMANDER E. G. SUTTON,** RN, (Retd). Mr Thomas was group welding engineer from 1946 until 1955, when he was appointed manager of John Thompson Conveyor Co., A year later he joined the boards of John Thompson Industrial Constructions Ltd., and the Owl Engineering Co., of Doncaster. A member of the Institute of Welding for several years and a past chairman and secretary of its Wolverhampton branch, Mr. Thomas has been a British delegate on several international welding missions. After serving for 23 years in the Royal Navy and retiring in 1955, Commander Sutton joined the Ordnance Division of John Thompson Conveyor Co., as manager. In 1957, when this Division became John Thompson Ordnance Co., he guided it in the manufacturing of equipment associated with a variety of weapons and in designing and manufacturing the charge fuel feed machines for Berkeley Nuclear Power Station.

A 26 year old engineer, **MR. DAVID E. BURTON,** BSc(Eng.), has been appointed to be in charge of the London technical sales department of Rocol, Ltd., the specialist developers and manufacturers of molybdenised and other industrial lubricants. The decision to appoint an experienced young man was taken so that customers may have the benefit of the most up-to-date technical knowledge. Mr. Burton was born in Streatham, London, and educated at Hampton Grammar School, Middlesex, and the Battersea College of Technology, where he graduated in mechanical engineering. He then pursued for two years a post-graduate course in production engineering at the Hawker Aircraft, Ltd., Kingston, which gave him a very wide experience in most aspects of mechanical engineering and machine tools, and was then appointed assistant works manager to the Hanworth Engineering (Aircraft) Co., Ltd., Sunbury-on-Thames, Middlesex.

MR. K. S. PHILLIPS, BSc(Eng.), ACGI, AMIEE, has been appointed sales controller of Research and Control Instruments Ltd. Among other duties, he will be responsible for the co-ordination of all sales staff activities. After training as an electronics engineer at the City and Guilds College, Mr. Phillips joined Siemens Edison Swan Ltd., where he has been for the past 20 years.

Recent engineering and commercial appointments announced by the Metropolitan-Vickers Electrical Co., Ltd., include those of **MR. C. F. SAUNDERS,** AssocMCT, AMIEE, MInstW, formerly chief engineer, heating and welding department, as chief engineer, standards department; **MR. G. H. MOULE,** formerly assistant chief engineer (heating), heating and welding department, as chief engineer heating and welding department; **MR. R. F. MANSFIELD,** AMIEE, as assistant sales manager, industrial control department; and **MR. F. CROWTHER,** AssocMCT, AMIEE, as assistant chief engineer (design), industrial control department. Mr. Saunders joined M-V (then British Westinghouse) in 1916 as a school apprentice. With a break for military service, 1917-19, he was associated with the motor engineering department, successively as design engineer, technical assistant, and chief of the estimating section. In 1947 he was appointed chief engineer, welding department, and in 1954 became chief engineer, heating and welding department, Mr. Moule received his technical education at Croydon Central Polytechnic and Liverpool Technical College. He gained experience with the Jackson Electric Stove and English Electric companies, and went to M-V as a development engineer in the heating element department in 1938. He was appointed engineer-in-charge of the heating element department in 1953. In 1954 the latter was merged with the Welding Department and Mr. Moule was appointed assistant chief engineer of the new department in 1956. Mr. Mansfield received his technical education at Faraday House (silver and gold medallist) and joined M-V in 1937 as a college apprentice. Afterwards he joined industrial control sales department, working as sales engineer until 1955, and on administrative duties from then until his present appointment. Mr. Crowther received his technical education at Manchester College of Technology, joining M-V as an apprentice in 1928. Following his apprenticeship, he worked successively as draughtsman, engineer, and engineering section leader in industrial control engineering department.

MR. H. G. NELSON, MInstCE, MIMechE, MIEE, the managing director of The English Electric Co., Ltd., has been appointed deputy chairman of D. Napier & Son, Ltd.; Marconi's Wireless Telegraph Co., Ltd.; Marconi Instruments, Ltd.; English Electric Valve Co., Ltd.; Vulcan Foundry, Ltd.; and Robert Stephenson & Hawthorns, Ltd.—all subsidiaries of English Electric. He also becomes deputy chairman of the associated company, The Marconi International Marine Communication Co., Ltd.

NUCLEAR NEWS

- **Time Reversal Invariance** *(This page)*
- **Control Course at Harwell** *(Page 111*
- **U.K. Firms at U.S. Show** *(Page 112)*

SCIENTISTS of the Argonne National Laboratory and the University of Chicago have shown that fundamental interactions between sub-atomic particles are unchanged under reversal of time. The principle involved is called time reversal invariance. It means if all motions of particles were reversed at the same time, they would proceed, following the same laws as before, to retrace their previous paths in the reverse direction. The scientists have demonstrated that time reversal invariance is valid in the decay of free neutrons, and thus by implication in all basic physical processes. Dr. Roy Ringo, a senior physicist at Argonne and spokesman for the research team, used billiard balls as symbols to explain the process. Two billiard balls collide, then separate, changing their directions. If the balls are reversed, as in a motion picture run backwards, would they retrace their paths? The answer is yes, providing such modifying forces as friction are ignored. In the case of the sub-atomic particles used in the Argonne experiments, forces such as friction are not present. Dr. Ringo pointed out that time reversal does not hold in large-scale processes such as life, because these processes involve so many particles, and the odds are astronomically against their " lining up " in such a way as to produce a physical reversal of time. In the Argonne experiments, neutron decay products were not reversed to form neutrons. Rather, the study concerned two types of neutrons whose " internal motions " were the reverse of each other. These neutrons were found to have the same decay pattern in certain crucial respects. Dr. Ringo said this, according to widely accepted theoretical views, is equivalent to observing invariance under time reversal. He added that the experiments—performed with the aid of an Argonne nuclear reactor—are the most sensitive of this type yet made. Scientists used " slow " beams of neutrons streaming from the sides of Argonne's Chicago Pile 5 (CP-5) heavy water research reactor for the investigations.

Scots Heat Research

THE Atomic Energy Authority has agreed to sponsor a research project on heat transfer in the Mechanical Engineering Laboratories of Robert Gordon's Technical College, Aberdeen. Mr. John F. Hall, chairman of the governors, congratulated Mr. Harry Hampson, head of the department, on the honour which the UKAEA had conferred on the college, when he recently announced the project. The Aberdeen college along with Aberdeen university has been co-operating since the start of the Dounreay project on the training of all grades of technicians and scientists for nuclear energy work, and has already made a valuable contribution to the provision of suitable employees. The isolation of Dounreay and the lack of educational facilities was initially seen as a handicap to recruitment and training. The new Thurso College will supplement the work which is being done in Aberdeen.

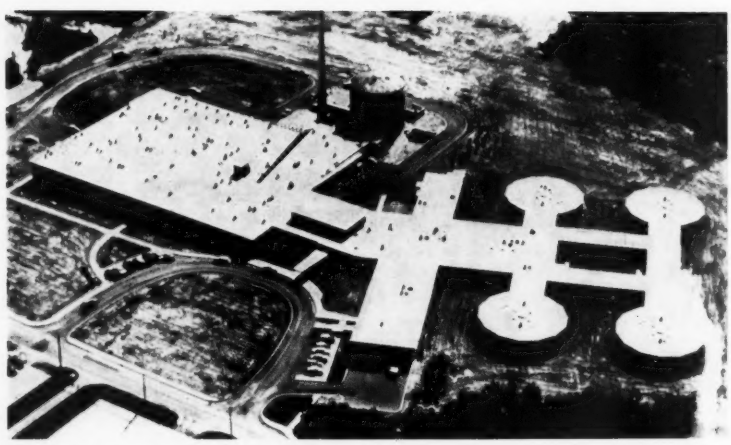
N-Materials Supply

THE statute regulating the operation of the nuclear supply agency which is to be set up by Euratom has been published. The agency will have the right of option on all ores, source materials and special fissionable materials produced in the Euratom countries and an exclusive right of concluding contracts relating to the supply of ores, etc., coming from inside and outside the Euratom countries. The agency, which will be financially independent, will be operated on commercial lines, but will not make a profit except in the case of a shortage, it is reported.

Let the People Know

AN information centre has been opened at the London office of the United Kingdom Atomic Energy Authority, 11, Charles II Street, S.W.1. Its purpose is to provide a convenient centre in London where members of the public, commercial firms and other organizations may consult published unclassified material (i.e., with no security restrictions) and seek advice on sources of information on United Kingdom atomic energy matters. A collection of UKAEA Unclassified Reports is available for reference. Indices and abstracts of atomic energy literature are filed and publications about the work of the Authority are available. The centre forms part of the public relations branch of the authority. The facilities which it offers are complementary to the already well established information services provided by the Authority at Harwell, Risley and, to a limited extent, Aldermaston, for dealing with scientific and technical enquiries. Next to the centre is a photographic library which holds a collection of some 8,000 photographs covering many aspects of nuclear energy. Prints may be purchased out of stock or ordered to suit particular requirements. The library also holds stocks of slides in both colour and black and white which are available on loan. The centre and library are open from Mondays to Fridays inclusive between 9.30 a.m. and 5.0 p.m. The telephone number is WHItehall 6262.

U.S. N-Medical Centre



Officially opened at Brookhaven, near New York, recently was America's first complete nuclear medical centre. It houses a reactor specially designed for medical research and treatment work. The aerial view slows clearly plan of the centre, with four circular hospital wings adjoining the oblong research building

Popular Course

A SECOND course on the control and instrumentation of reactors will be held at the Harwell Reactor School from July 7th-17th, 1959, and will be open to British and overseas students. The first course, held in October, 1958 was heavily overbooked and a total of 98 attended. It lasted for five and a half days, but as a result of the experience gained from this course, it has been decided to extend the second course to nine days. The course is primarily intended for those who have a direct interest in the control and instrumentation of nuclear reactors, and it will be assumed that participants have some knowledge of the basic principles of these subjects. The topics to be treated will include:— Revision of elementary reactor kinetics, control and instrumentation; automatic control of reactors and nuclear power plants; application of computers; reactor transfer functions and function analysers; neutron flux scanning; radiation detectors and their siting in reactors; reactor safety circuits; conventional instrumentation; use of transistors in reactor instrumentation; burst slug detection; spatial instabilities in reactors; and data reduction problems on large reactors. In addition to the lectures there will be visits to zero energy and high flux research reactors and other relevant parts of the Harwell Establishment. The fee for the course will be 50 gns., exclusive of accommodation, and application forms, available from the Reactor School, must be returned by May 7th, 1959, to:—The Principal, Reactor School, Atomic Energy Research Establishment, Harwell, Didcot, Berkshire.

Boiler Shells

SHELLS for two of the three sodium heat-exchangers to be installed at the Enrico Fermi Nuclear Power Plant at Monroe, Michigan, have been delivered. Made by Alco Products, Inc., at their Dunkirk, N.Y., works, the shells are 88 in. in diameter and nearly 31 ft long. Each weighs 46,000 lb. They are fabricated in solid stainless steel and extensive tests were performed on design prototypes before construction of the actual units was started. The Enrico Fermi station, due for initial operation in 1960, was designed by Atomic Power Development Associates, a non-profit corporation formed by 43 companies interested in making practical use of nuclear energy as a power source. It will be based on a sodium-cooled breeder reactor system. The exchangers will transfer heat from a primary sodium stream to a secondary one. Each exchanger will have a design capacity of about 500m. B.t.u.

Valvular Show

A PRIVATE exhibition of valves and valve equipment is to be held by the English Electric Valve Co., Ltd., at the Kensington Palace Hotel, London, from March 17th-21st. Valves used for radar, broadcasting and communication equipment will be displayed, together with new types of storage tubes.

UKAEA MEN HONOURED

Three of the staff of the United Kingdom Atomic Energy Authority honoured in the New Year Honours List—(*left to right*) Mr. Peter Mummery, of Harwell, who received the OBE, Mr. F. S. Dennard, of Aldermaston, the MBE, and Mr. I. H. Hogg, of Risley, the MBE. Further details with the names of other recipients are given on page 109

Neutron Tracing

THE International Atomic Energy Agency has awarded a research contract to the Physical Institute of the University of Trieste, Italy, as part of its programme of developing health and safety measures for the peaceful uses of atomic energy. With the financial assistance of IAEA, the Institute will undertake a research project

NUCLEAR NEWS

for the investigation and development of a new method of detecting fast neutrons as they occur in space surrounding reactors and other neutron sources. The same method might eventually be adopted for detecting very small quantities of Alpha-particle emitting substances in the human body. The Agency will contribute $7,000 to the project.

A Take Over

COMBUSTION Engineering, Inc., have filed a registration statement with the Securities and Exchange Commission relating to the acquisition of General Nuclear Engineering Corporation through an exchange of stock. General Nuclear is engaged in rendering design, engineering, advisory, research and development services in the field of nuclear energy and is associated with several important nuclear power projects. It will be operated by Combustion Engineering as a subsidiary. Dr. Walter Zinn, president of General Nuclear, will be in charge of all of Combustion's nuclear power activities. Combustion have been active in the nuclear field for more than 12 years and have extensive facilities for the design, development, manufacture and testing of reactor systems, including both light and heavy components. Work now in process at these facilities includes fuel element fabrication, core assembly and manufacture of a variety of heavy components. The company were recently awarded a contract by the Atomic Energy Commission for the operation of the Army Low-Power Reactor—a boiling water type—at the National Reactor Testing station in Idaho. Another recent AEC project, in which the company will participate in association with the Stone & Webster Engineering Corporation, is a study of an advanced type of pressurized water power reactor.

Firm Move

THE Mulberry Co. of London are moving during the early part of February to new premises at Castle Wharf, Orchard Place, London, E.14. Telephone number is EASt 4471.

Sub. Plans

THE contract for the American nuclear reactor to be used in Britain's first nuclear powered submarine, *Dreadnought*, is still under negotiation, says the Admiralty. No date for signing it has yet been fixed. The purchase of an American reactor is the outcome of the agreement signed between the U.S. and Britain last summer for mutual defence purposes. The *Dreadnought* project is being carried out by the Vickers Nuclear Engineering Co., which was formed by Vickers Armstrong, Ltd., Rolls Royce, Ltd , and Foster Wheeler, Ltd.

Gaining the "Know How"

COURSES in nuclear engineering, nuclear particle techniques, nuclear physics, nuclear radiation shielding, nuclear reactor engineering, nucleonic techniques and measurements, radioisotopes, and reactor instrumentation available at colleges of technology, technical colleges and polytechnics in London and the Home Counties are listed in the "Bulletin of Special Courses in Higher Technology." Published by the London and Home Counties Regional Council for Technological Education, the Bulletin is issued in two parts—Part I, listing the courses in the Autumn term, and Part II, courses in the Spring and Summer terms. Single copies of each part are obtainable from the Council at Tavistock House South, Tavistock Square, W.C.1.

Atom Fair

THE Atomic Industrial Forum's Fifth Atomfair is to be held at the Public Auditorium, Cleveland, Ohio, from April 5th-10th. Exhibits will include nuclear fuel elements, radioisotopes, beryllium and zirconium components, and radiation detectors and recorders. Services such as analysis, waste disposal and the erection and servicing of complete reactor installations will also be publicized. British firms will be among the exhibitors.

Poles Visited

RECENT visitors to nuclear energy research installations in Poland were top IAEA officials, including chairman Carlos Bernardes, secretary-general Sterling Cole, Dr. Paul Jolles, Professor H. de Laboulaye and Dr. Karl Griber. Their host was Mr. Wilhelm Billig, who is in charge of the Polish nuclear energy programme and is vice-chairman of the IAEA.

Accident Report

THE " Report on Electrical Accidents and their Causes, 1957," recently published for the Ministry of Labour and National Service, contains information interesting and useful to all industrial users and public supply engineers on the subject of electrical safety. Among various topics discussed is the application of electrical instrumentation to safety problems. A number of applications are mentioned, such as the use of strain gauges (which measure strains and stresses in structures or machines) to give warning of an excessive overturning movement on cranes, and the employment of telecommunication techniques for enhancing safety in industry. Special precautions in instrumentation and control at nuclear energy power plants and factories are also mentioned. In analysing the year's accidents, the report mentions that in spite of the continued rapid increase in the use of electricity for power, the number of accidents per year is now virtually steady and, if anything, falling. There are, in fact, only a little over 20 per cent. more electrical accidents than in 1938; and it is shown that this increase is very largely accounted for by the number of cases of welder's conjunctivitis or eye-flash, which are comparatively trivial. Under the heading of " Safety," the adequacy of the conductors commonly used for temporarily earthing switchgear and busbars is discussed together with some aspects of switchgear failures, in particular isolating switches, " auto-reclose " switches and the on-load tap changing equipment of large transformers. A section of the report deals with problems associated with industrial electrical control gear and circuitry, and practical advice is given to enable users to avoid some of the circumstances which lead to danger and accidents.

NUCLEAR NEWS

District Offices

EVERSHED & Vignoles Ltd., have opened a district office at 14, Yarm Lane, Stockton-on-Tees, (Telephone: Stockton 64288). The office is in the charge of Mr. W. H. M. Hoyle, who has represented the company since 1955. The company's northern area office at: 116, Manningham Lane, Bradford 8, (Telephone: 28083) continues to hold an overall responsibility for the northern counties and, in addition, has a staff of fully trained servicing engineers. Office hours will be 9 a.m. to 12.30 p.m. and 2 p.m. to 5 p.m., Mondays to Fridays inclusive.

U.S.-French Tie Up

AN agreement has been signed between Forges et Ateliers due Creusot, of France, and the Westinghouse Electric International Co., of America, for co-operation in nuclear reactor construction. A company is to be formed, called Fromatome, which will be capable of building complete reactors. Initial capital and the share participation have yet to be decided. Creusot have also concluded an agreement for the exchange of technical information with Westinghouse.

1,000 Students

The radioisotope school attached to the Atomic Energy Research Establishment, Harwell, recently received its 1,000th student. The school was established in April, 1951, to provide training in the safe and effective use of radioisotopes for applications in research and industry. During that time 53 basic courses, each of four weeks duration, and 24 specialized courses have been held. Students have come from some 50 countries, 64 per cent. of them being from Britain and 12 per cent. from the Commonwealth.

Past and Future

" POWER for the Future " is the title of a booklet published by The Electricity Council, which is now the central body representing the whole of the electricity supply industry in England and Wales. Prepared in connection with the Electricity (Borrowing Powers) Bill and forming a sequel to the similar publication, " Power and Prosperity," of the former British Electricity Authority in 1954, the booklet outlines the development of electricity supply in the past and gives an estimate of the rise in demand over the next few years, together with an indication of the cost up to 1964/65 of providing the power requirements of an expanding national economy.

Economic Aspects of U.K. Power

(*Continued from page 101*)

rise with reductions in capital cost is far from proven as yet and will depend on the successful outcome of further experimental work and operating experience.

Consideration has also been given to the possible use of conventionally fired superheaters on nuclear stations, which might appear to be an attractive proposition with the relatively poor steam conditions at present available. Assessments have shown that on present designs an increase of output capacity by approximately 20 per cent. could be achieved at an incremental capital kilowatt cost of not much more than half that for a conventional coal or oil fired station, and that the efficiency of burning the coal or oil would also be somewhat greater than that of an advanced conventional power plant. This course, however, has not been adopted for a number of reasons.

Firstly, siting considerations would make it extremely difficult to find locations in the United Kingdom which met the criteria for both nuclear and conventionally fuelled stations. Secondly, technical considerations lead to the conclusion that it would be unwise to build " mixed fuel " plants until adequate experience has been gained on the various components, particularly the large superheaters concerned. Finally, as regards the future, the return from conventionally fired superheating is reduced if outlet gas temperatures from reactors can be increased. However, the situation has continually to be watched carefully in view of the possible capital and running cost savings which might accrue if the siting and technical problems could be overcome.

(*To be continued*)

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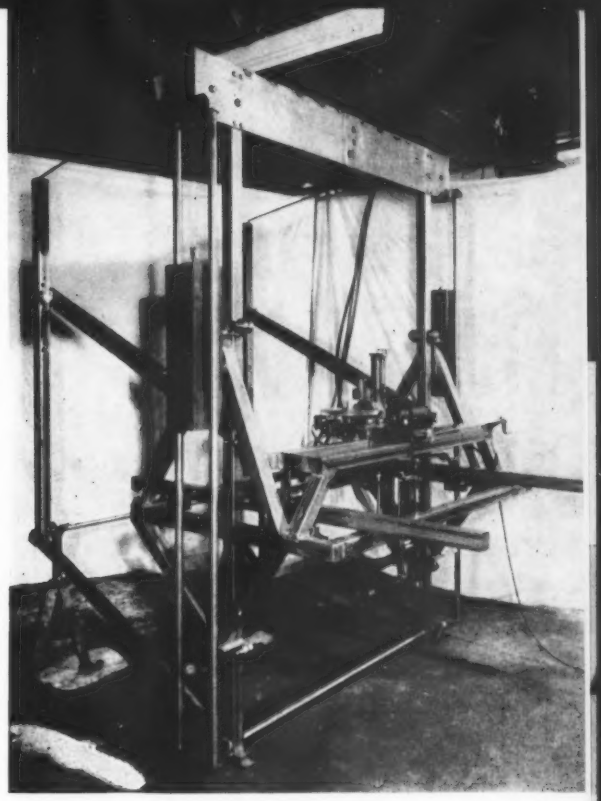
Machine for CUTTING HOLES in CURVED SURFACES

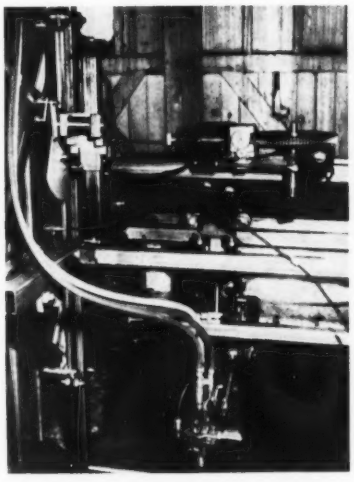


THIS article describes a special purpose oxygen cutting machine designed to cut non-radial holes in the spherical crown of the reactor shell and to level the holes inside and outside in preparation for welding. The machine has four legs, the front and rear pairs of which are connected by parallel link mechanism, the links of which are parallel to the surface of the sphere when the four feet are resting on the sphere. The four legs are adjusted to be vertical when the hole is cut.

The mechanism generating the circle is carried by a " U " frame which is free to move vertically on the rear pair of legs and two balance weights are fitted to facilitate this movement. This frame carries, on rollers, a horizontal " H " frame which is free to move fore and aft and which, in turn, carries a cross-carriage supported on rollers which is free to move across the cross bar of the " H " frame.

Parallel to Surface

The " H " frame carries a vertical member with an adjustable swivelling slide fitted with rollers engaging a longitudinal projection on one of the connecting links of the parallel link motion, so that in moving fore and aft the " H " frame, and all it supports, moves up and down so that all these parts move on a path parallel to the tangent to the surface of the sphere, but the " U " frame moves vertically only.



The cutting head and drive mechanism of the machine

A motor is fitted to the " U " frame and through worm reduction gearing to a crank rotating about a vertical shaft. A rotatable member, carried by the cross carriage on the cross bar of the " H " frame, is attached to this crank at a radius corresponding to the radius of the hole to be cut. As this crank is rotated, the cross carriage moves in a circle, but remains parallel to the central plane. This circular movement splits up into a cross-wise movement of the cross-carriage relative to the " H " frame and a fore and aft movement of the " H " frame relative to the legs accompanied by an up and down movement of both the " H " frame and the " U " frame.

Rock Any Direction

The oxygen cutter is mounted on a rocking parallel link mechanism below the cross carriage in such a manner that when disconnected it can rock in any direction always pointing to a fixed spot some $^{5}/_{16}$ in. below the bottom of the cutter when it is in its lowest position. The mechanism controlling the cutter is attached to a quadrant carried by the vertical shaft, the upper end of which is attached to the rotating crank. The quadrant always lies in the same plane as the crank so that as the latter rotates the quadrant also rotates.

To cut a parallel hole the mechanism carrying the cutter is attached to the centre of rotation of the quadrant when the axis of the cutter remains vertical. To cut a conical hole or to bevel a hole the cutter mechanism is attached to the quadrant at a point away from the centre of rotation to one side or the other depending whether a top or bottom bevel is required.

Remote Control

When the centre of the hole to be cut is at a large angle to the radial through the centre of the hole and the sphere, it is desirable to give a differential bevel angle to the cut, whereby the bevel angle is reduced at the highest point and increased at the lowest. This is affected by giving a bias to the cutter on a subsidiary quadrant incorporated in the cutter mechanism.

The oxygen cutter itself is inaccessible for adjustment and is remotely controlled.

Makers of the machine are Oxhycarbon Ltd.

Welding Equipment and Processes

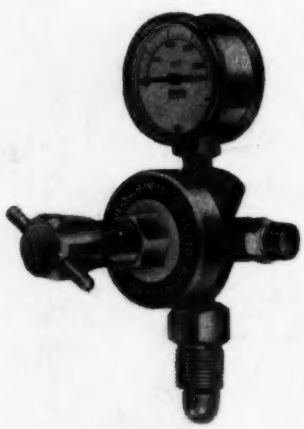
We are publishing details of equipment and processes we were unable to include, through pressure of space, in last month's special issue on welding. The regular "Equipment and Materials" feature will appear again in next month's issue. Readers who want further information on items mentioned in these pages should use the coupon at the bottom of the page.

Spot Welders

In the business for over 20 years, Sciaky Electric Welding Machines Ltd., of Slough, Bucks, manufacture a wide and varied range of equipment, their speciality being in spot welders. Features of the "Rapid" range of welders include speeds of 250 fully controlled spot welds/min, instantly detatchable plug-in electronic timer, an electrode force well up to B.S. requirements, and "squeeze," "weld," and "dwell" timers that apply electrode force before, during and after the welding period. Three models, all with optional throat dimensions, are available in the range—15, 25 and 50 kVA. Another Sciaky unit is the "Speedforge" projection welder, available in 40, 75, 150, 300, 500 and 600 kVA sizes. Fully automatic, it is made for all purpose operations by unskilled labour. **(FY 1)**

Gas Regulators

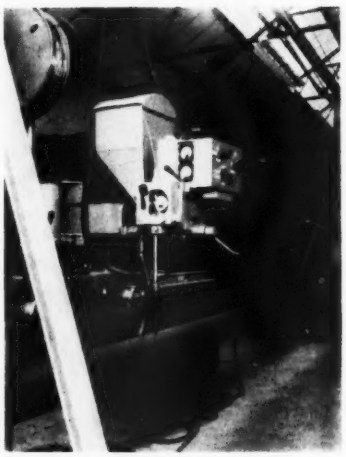
A new simple and robust regulator suitable for use with most gases has been brought on to the market by British Industrial Gases Ltd., of Enfield, Middx. Four models are available: No. 67 for CO_2, No. 68 for acetylene, No. 69 for oxygen and No. 70 for propane. Flow rates as tested by the firm are as follows: at a pressure of 5 lb/sq.in. 340 cu.ft/hr; 10 lb/sq.in., 480 cu.ft/hr; 20 lb/sq.in., 780 cu.ft/hr; and at 30 lb/sq.in., 1,000 cu.ft/hr. At 40 lb/sq.in. estimated flow is 1,200 cu.ft/hr and at 80 lb/sq.in. 1,800 cu.ft/hr. Another new product of British Industrial Gases is the B.I.G. hose clamp designed for keeping twin hoses neatly together. Simple to fit and adaptable for repeated use, they are available for fitting to standard hose. **(FY 2)**



One of the new range of regulators made by British Industrial Gases Ltd.

Automatic Arc Welding

The Autopak automatic welding equipment made by Rockweld Ltd., of Croydon, Surrey, incorporates a new conception in automatic arc voltage control. Portable and easily operated, the Autopak can be used as a manual welder and at the same time it can be extended to any fully-automatic application. When not fully employed in running automatic submerged arc welds it is available for hand welding with ordinary coated electrodes. The automatic control equipment consists of components associated with the transformer and which are used to feed and control the automatic welding head. There are two items of control: the control unit itself and the welding circuit contactor panel. There are no electronic components. An adaptation of the twin motor control system has been adopted for a drive unit for the welding head carriage. This form of drive provides a 25 to 1 continuous speed variation. Irrespective of the speed of traverse selected, starting is smooth and fast, ensuring a clean start to the weld. The unit's well-protected welding head has been designed to take continuous wire feed when powered by the Autopak transformer. It is intended mainly for submerged arc welding. The standard head and rolls take $^3/_{32}$ in., $\frac{1}{8}$ in., $^5/_{32}$ in., $^3/_{16}$ in., and $\frac{1}{4}$ in. diameter bare coppered steel wire. Special rolls can be fitted for other processes. **(FY 3)**



An Autopak welding unit in use

Bronze Welding Rods

Pioneers in the production of welding rods and fluxes, the Suffolk Iron Foundry (1920) Ltd., of Stowmarket, have been

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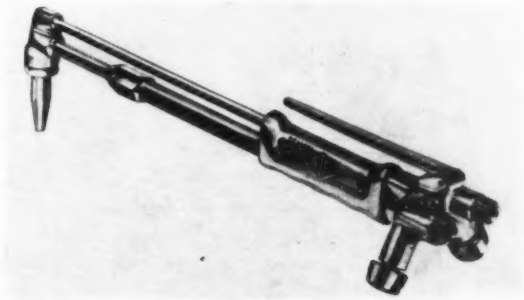
welding specialists for over 40 years. Exclusively concerned with oxy-acetylene welding they have contributed to the general advances in quality and performance of almost every ferrous and non-ferrous welding rod for most commercial metals. Their most outstanding contribution has been the development of the bronze rod, and, in this connection, they have introduced many new types which greatly simplify the actual welding operation. Universally known as "Sifbronze" welding, the process has the advantage of low temperature application (it is in the region of 750° C. to 950° C.) and can be used on all types of metals except aluminium at high welding, or brazing speeds, and with a minimum of distortion. Research into rods and fluxes has also been accompanied by development of equipment. For instance, recent trends in the design of blowpipes of both the "injector" and "non-injector" type have been towards lightness in weight and ease of handling. To meet this demand, Suffolk Iron Foundry produced the Demon blowpipe range, very light high pressure blowpipes of one-piece nozzle construction, they employ patented gas mixing devices which ensure correctly proportioned feeds and automatic intermixing of gases calculated to prevent flashback and backfire. In the field of gas regulation, the "Sifbronze" regulator is furthering the case for single-stage gas pressure control. The special feature of this regulator is the easy replacement of main valve and diaphragm. **(FY 4)**



The "Sifbronze" Demon cutting blowpipe

Test Service

Tests recently carried out by the Metal and Pipeline Endurance Ltd., were for the evaluation of various competitive electrodes in the 4-6 per cent. chromium, ½ per cent. molybdenum class to discover the best possible electrode for all positional welding on both pipe joints and for various types of refinery installations. The tests embraced the pre-heating and stress relieving of joints, following which radiographic examination took place, when the pipe was afterwards cut up into coupons for face bends, and reduce tensile specimen tests. Other coupons were used under a microscope to assess the micro fissuring tendencies of the welding metal, and also for hardness surveys on the transverse cross section. Mapel also carried out evaluation tests on competitive electrodes for plain carbon ½ per cent. molybdenum steel, this work being devoted entirely to plate work, where horizontal/vertical welds were to be made, and also welds in the true vertical position. Pre-heating and stress relieving were again required. Also tested were various competitive electrodes on evaluation tests on 25/20 stainless steel, where electrolytical polishing was followed by a fissuring count under a low power magnification. Mapel offer a comprehensive service not only for pressure vessels but also for tanks, structures and pipework with a research department for carrying out tests such as described above. **(FY 5)**

Radiographic Equipment

Newton Victor—the X-ray department of Metropolitan-Vickers—has radiographic and crystallographic equipment suitable to meet all the requirements of nuclear engineering and its supporting industries. One of the latest developments is the industrial cobalt container using radioactive cobalt-60, which offers the equivalent in many respects of an X-ray tube operating at 3m. volts. The Newton Victor cobalt container housing 1,000 or 1,500 curies of cobalt will produce in the 3-6 in. thickness range, in economical exposure times, radiographs with a density of 2 showing penetrameter sensitivities comparable with those taken by X-rays. As this cobalt unit can be used up to a distance 36 times the specimen thickness, a specimen say 4 in. thick and 5 ft or more in length can be examined in a single exposure of 10 min. This indicates the value of the cobalt container for the inspection of the larger cylindrical or spherical pressure vessels. In addition, a range of accessories is available, such as cassettes, radiograph illuminators and comprehensive X-radiation protective equipment ranging from lead-rubber gloves and aprons to lead-ply panelling. In this last instance the company offers a complete service to cover its correct application for buildings, screens, etc. **(FY 6)**

Increased Output

The complete welding cycle, including the clamping of the work pieces, is carried out on the "Meritus" P.B.3 butt welding machine by one stroke of the foot pedal. The single action operation speeds up production by at least three times as compared with earlier machines. The welding transformer has been specially designed to allow for high production speeds and is efficiently insulated and impregnated, the output being controlled by a 4-position snap action tapping switch. Welding current duration is controlled by an electrically energized contactor in conjunction with a microaction limit switch which can be adjusted to give any desired amount of collapse at the welding faces. Output of the machine is 3 kVA. **(FY 7)**

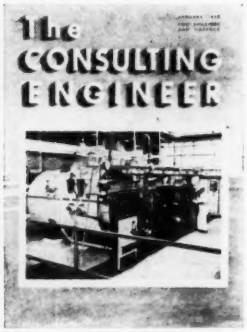
Welding Blowpipe

Weighing only 15 oz complete with nozzle and hose connections, the new Weldcraft high pressure TS blowpipe, made by Weldcraft Ltd., of Purley Way, Croydon, Surrey, is claimed to be the lightest in production to-day. Specially designed to reduce fatigue on prolonged welding operations it is ideally suited for use by female labour on sheet metal and light repetition work. A particularly interesting feature of the blowpipe is a range of swaged copper nozzles which are offered as an alternative to the nine standard nozzles, specified for welding steel from $^{1}/_{32}$ in. to $^{5}/_{16}$ in. in thickness. In its basic form, the TS comprises a blowpipe with neck and six nozzles for welding up to $^{5}/_{32}$ in. Other sets include six swaged nozzles (TS2); nine standard nozzles (TS3); and nine swaged nozzles (TS4). Gas consumption is quoted at 1 cu.ft/hr with No. 1 nozzle, to 25 cu.ft/hr with the No. 9, depending on the skill of the operator and mass of metal. Oxygen pressures varying from 3 lb/sq.in. to 7 lb/sq.in. **(FY 8)**

For Cutting Operations

The portable oxy-acetylene set supplied by Siebe, Gorman & Co., Ltd., can be used for cutting or welding in normally inaccessible places. It is also useful for emergency rescue work or emergency repairs. The apparatus consists of a carrying frame, an oxygen and an acetylene reducing valve, cutter or welder with 5 ft of tubing; harness and pocket for carrying cutter, 11 cu.ft oxygen cylinder and 10 cu.ft acetylene cylinder. The cutter is suitable for cutting up to ¼ in. mild steel plate. The average consumption of acetylene varies between 9 and 10 cu.ft/hr and the oxygen consumption between 27 to 60 cu.ft/hr, dependent on the work being done, the skill of the operator and material. **(FY 9)**

Portable acetylene equipment made by Siebe, Gorman & Co., Ltd.



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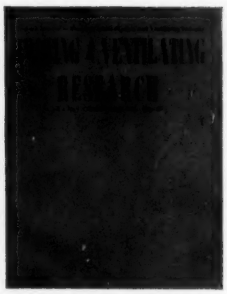

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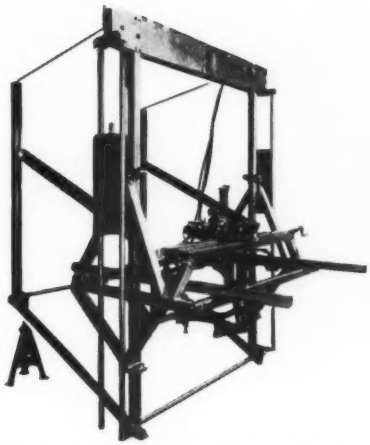

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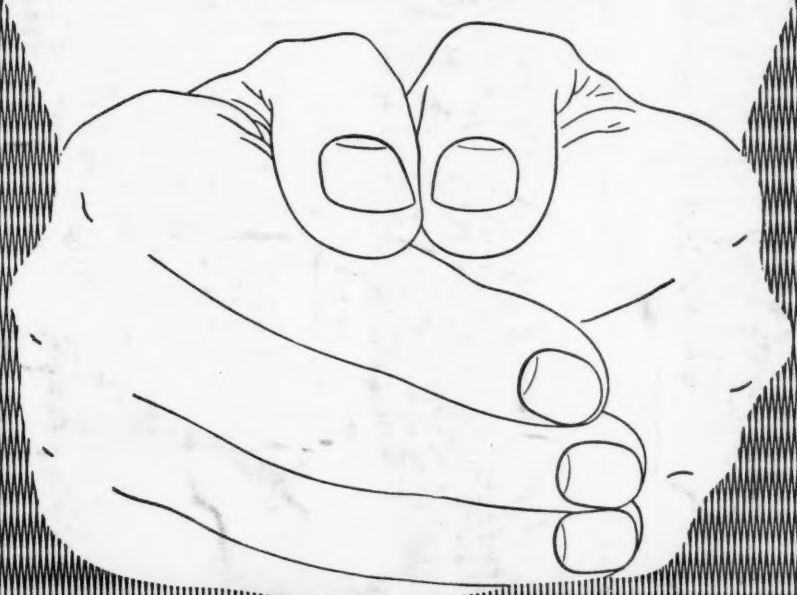

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